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TESTING MATERIALS

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PROCEEDINGS
OF THE
TWENTY-FOURTH ANNUAL MEETING

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NEW AND REVISED TENTATIVE STANDARDS
TECHNICAL PAPERS

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CONTENTS.

PROCEEDINGS.

PAGE

Summary of the Proceedings of the Twenty-fourth Annual Meeting 11
The Influence of the Work of the American Society for Testing Materials upon the Execution of Public Works: Annual Address by the President, George S. Webster 39
Annual Report of the Executive Committee 47

COMMITTEE REPORTS.

Ferrous Metals.

Report of Committee A-1 on Steel 66
  Appendix. Proposed Revisions of Standards and Tentative Standards for Steel 75
  Addendum to Report of Committee A-1 87
Report of Committee A-2 on Wrought Iron 90
  Appendix. Proposed Revisions of Standards and Tentative Standards for Wrought Iron 94
Report of Committee A-3 on Cast Iron 96
  Addendum to Report of Committee A-3 98
Report of Committee A-4 on Heat Treatment of Iron and Steel 99
Report of Committee A-5 on Corrosion of Iron and Steel 103
  Report of Sub-Committee II on Preservative Metallic Coatings for Metals 105
  Report of Sub-Committee III on Inspection of the Fort Sheridan, Pittsburgh and Annapolis Tests 106
  Report of Sub-Committee V on Total Immersion Tests 157
  Discussion 191

Non-Ferrous Metals.

Report of Committee B-1 on Copper Wire 195
Report of Committee B-2 on Non-Ferrous Metals and Alloys 198
  Addendum to Report of Committee B-2 208

Cement, Lime, Gypsum, and Clay Products.

Report of Committee C-2 on Reinforced Concrete 210
Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete 212
Report of Committee C-3 on Brick 284
Report of Committee C-4 on Clay and Cement Sewer Pipe 285
Report of Committee C-6 on Drain Tile 286
Report of Committee C-7 on Lime 289
  Appendix. Cooperative Tests on Effect of Hydrated Lime on Concrete Mixtures 294
  Discussion 302

PAGE
Report of Committee C-8 on Refractories 315
Report of Committee C-9 on Concrete and Concrete Aggregates 317
Discussion 322
Report of Committee C-10 on Hollow Building Tile 324
Report of Committee C-11 on Gpysum 326

Miscellaneous Materials: Preservative Coatings, etc.

Report of Committee D-1 on Preservative Coatings for Structural Materials 329
Report of Sub-Committee III on Testing of Paint Vehicles 333
Report of Sub-Committee V on Linseed Oil 334
Report of Sub-Committee VI on Definitions of Terms used in Paint Specifications 341
Report of Sub-Committee XI on Paint Thinners Other than Turpentine 342
Report of Sub-Committee XII on Turpentine 344
Report of Sub-Committee XIV on Preparation of Iron and Steel Surfaces for Painting 345
Appendix. Report of Inspection of Test Panels, October, 1920 348
Report of Sub-Committee XV on Specifications for Pigments Dry and in Oil when Marketed in That Form 350
Report of Committee D-2 on Petroleum Products and Lubricants 351
Report of Sub-Committee I on Petrolatum 354
Appendix. Melting Point of Petrolatum 357
Report of Sub-Committe II on Gas Absorbent Oil 360
Report of Sub-Committee III on Paraffin Wax 360
Report of Sub-Committee IV on Grease 361
Report of Sub-Committee V on Viscosity 362
Report of Sub-Committee VI on Color 363
Report of Sub-Committee VII on Sulfur Determination and Differentiation 365
Report of Sub-Committee VIII on Distillation 367
Report of Sub-Committee IX on Precipitation 367
Report of Sub-Committee X on Oxidation at High Temperatures 368
Report of Sub-Committee XII on Flash 368
Report of Sub-Committee XIII on Saponification 369
Appendix. Results of Cooperative Work for Saponification Number on Mixtures of Oils Submitted to Committee Members 371
Report of Sub-Committee XIV on Water and Sediment 373
Report of Sub-Committee XVI on Cloud and Pour Test 374
Report of Committee D-4 on Road and Paving Materials 375
Report of Committee D-5 on Coal 381
Report of Committee D-6 on Coke 383
Report of Committee D-7 on Timber 384
Report of Committee D-9 on Electrical Insulating Materials 392
Appendix I. Joint Comparative Tests of Spark Gaps for Testing Transformer Oils 397
Appendix II. Procedures in Sludging Tests for Transformer Oils 407
Report of Committee D-10 on Shipping Containers 409
Report of Committee D-11 on Rubber Products 412
Minority Report 419
Discussion 421

PAGE
Report of Committee D-13 on Textile Materials........................ 425
Report of Committee D-14 on Screen Wire Cloth........................ 427

Miscellaneous Subjects.

Report of Committee E-1 on Methods of Testing........................ 428
Report of Committee E-4 on Metallography........................ 436
Report of Committee E-6 on Papers and Publications........................ 437
Report of Committee E-8 on Nomenclature and Definitions........................ 440

A.S.T.M. TENTATIVE STANDARDS.

Submitted or revised at 1921 Annual Meeting.

A. FERROUS METALS.

Tentative Specifications for:

A 70–21 T. Boiler and Firebox Steel for Stationary Service........................ 447
A 71–21 T. Carbon Tool Steel........................ 452
A 78–21 T. Steel Plates for Forge Welding........................ 454
A 82–21 T. Cold-Drawn Steel Wire for Concrete Reinforcement........................ 459
A 83–21 T. Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes........................ 461
A 56-21 T. Iron and Steel Chain........................ 468
A 85–21 T. Merchant Bar Iron........................ 474
A 86–21 T. Hollow Staybolt Iron........................ 478
A 46–21 T. Cast-Iron Car Wheels........................ 481

B. NON-FERROUS METALS.

Tentative Specifications for:

B 17–21 T. Non-Ferrous Alloys for Railway Equipment in Ingots, Castings, and Finished Car and Tender Bearings........................ 486
B 30–21 T. Brass Ingot Metal, Graded and Ungraded, for Sand Castings........................ 491
B 39–21 T. Nickel........................ 495

Tentative Methods of:

B 40–21 T. Chemical Analysis of Aluminum and Light Aluminum Alloys........................ 499
B 41–21 T. Chemical Analysis of Nickel........................ 522

C. CEMENT, LIME, GYPSUM, AND CLAY PRODUCTS.

Tentative Specifications for:

C 32–21 T. Clay Sewer Brick........................ 527
C 5–21 T. Quicklime for Structural Purposes........................ 533
C 6–21 T. Hydrated Lime for Structural Purposes........................ 537
C 33–21 T. Concrete Aggregates........................ 544
C 34–21 T. Clay Hollow Building Tile........................ 547
C 22–21 T. Gypsum........................ 553

Tentative Specifications for:

PAGE
C 23–21 T. Calcined Gypsum 556
C 35–21 T. Gypsum Plastering Sand 559
C 36–21 T. Gypsum Wall Board 560
C 37–21 T. Gypsum Plaster Board 562

Tentative Methods of:

C 25–21 T. Chemical Analysis of Limestone, Lime and Hydrated Lime 565
C 38–21 T. Test for Resistance of Fire-Clay Brick to Spalling Action. 577
C 39–21 T. Making Compression Tests of Concrete 579
C 40–21 T. Test for Organic Impurities in Sand for Concrete 585
C 41–21 T. Test for Sieve Analysis of Aggregates for Concrete 586
C 42–21 T. Securing Specimens of Hardened Concrete from the Structure 588
C 26–21 T. Testing Gypsum and Gypsum Products 590

Tentative Definitions of:

C 11–21 T. Terms Relating to the Gypsum Industry 600
C 43–21 T. Terms Relating to Hollow Tile 602

D. MISCELLANEOUS MATERIALS.

Preservative Coatings.

Tentative Specifications for:

D 13–21 T. Turpentine 604
D 77–21 T. Purity of Raw Linseed Oil from South American Seed... 613
D 78–21 T. Purity of Boiled Linseed Oil from South American Seed 614
D 79–21 T. Zinc Oxide 615
D 80–21 T. Leaded Zinc Oxide 617
D 81–21 T. Basic Carbonate White Lead 619
D 82–21 T. Basic Sulfate White Lead 621
D 83–21 T. Red Lead 623
D 84–21 T. Iron Oxide and Iron Hydroxide 625
D 85–21 T. Ocher 627

Tentative Definitions of:

D 16–21 T. Terms Relating to Paint Specifications 629

Petroleum Products and Lubricants.

Tentative Methods of:

D 86–21 T. Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products 631
D 87–21 T. Test for Melting Point of Paraffin Wax 638
D 88–21 T. Test for Viscosity of Fuel Oils and Other Oils of Similar Viscosity 642
D 89–21 T. Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Petroleum Products 643
D 90–21 T. Test for Sulfur in Naphthas and Illuminating Oils 644
D 91–21 T. Test for Precipitation Number of Lubricating Oils 648
D 92–21 T. Test for Flash and Fire Points by Means of Open Cup.. 651

Tentative Methods of:

PAGE
D 93-21 T. Test for Flash Point by Means of the Pensky-Martens Closed Tester.... 655
D 94-21 T. Test for Saponification Number.... 663
D 95-21 T. Test for Water in Petroleum Products.... 666
D 96-21 T. Test for Water and Sediment in Petroleum Products, by Means of Centrifuge.... 670
D 97-21 T. Test for Cloud and Pour Points of Petroleum Products.. 674

Road Materials.

Tentative Specifications for:

D 98-21 T. Calcium Chloride for Dust Prevention.... 679
D 99-21 T. Asphalt Cement, 40 to 50 Penetration.... 681
D 100-21 T. Asphalt Cement, 50 to 60 Penetration.... 682
D 101-21 T. Asphalt Cement, 60 to 70 Penetration.... 683
D 102-21 T. Asphalt Cement, 70 to 90 Penetration.... 684
D 103-21 T. Asphalt Cement, 90 to 120 Penetration.... 685
D 104-21 T. High-Carbon Tar for Surface Treatment, Cold Application.... 686
D 105-21 T. Low-Carbon Tar for Surface Treatment, Cold Application.... 688
D 106-21 T. High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).... 690
D 107-21 T. Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).... 692
D 108-21 T. High-Carbon Tar for Surface Treatment, Hot Application 694
D 109-21 T. Low-Carbon Tar for Surface Treatment, Hot Application 696
D 110-21 T. High-Carbon Tar Cement.... 698
D 111-21 T. Low-Carbon Tar Cement.... 700
D 112-21 T. Coal-Tar Pitch for Block Filler.... 702

Tentative Methods of:

D 113-21 T. Test for Ductility of Bituminous Materials.... 704
D 114-21 T. Test for Water in Bituminous Materials.... 706

Coal and Coke.

Tentative Definitions of:

D 121-21 T. Terms Relating to Coke.... 708

Insulating Materials.

Tentative Methods of:

D 48-21 T. Testing Molded Insulating Materials.... 711
D 115-21 T. Testing Insulating Varnishes.... 722
D 116-21 T. Testing Electrical Porcelain.... 727
D 117-21 T. Testing Transformer and Switch Oils.... 737

Shipping Containers.

Tentative Specifications for:

D 118-21 T. 4-One Boxes and Similar Type Boxes.... 741

Rubber Products.

Tentative Specifications for:

PAGE
D 27–21 T. Insulated Wire and Cable: 30-per-cent Hevea Rubber .. 746
D 14–21 T. Cotton Rubber-Lined Fire Hose for Private Fire Department Use 773
D 26–21 T. Cotton Rubber-Lined Fire Hose for Public Fire Department Use 778
D 46–21 T. Wrapped Air Hose for Use with Pneumatic Tools 784
D 60–21 T. Braided Air Hose for Use with Pneumatic Tools 788
D 54–21 T. Steam Hose 792
D 53–21 T. Rubber Belting for Power Transmission 795
D 69–21 T. Commercial Adhesive Tape for Electrical Purposes 799
D 119–21 T. Rubber Insulating Tape 802
D 120–21 T. Rubber Gloves for Electrical Workers on Apparatus or Circuits not exceeding 3000 volts to Ground 805

Textile Materials.

Tentative Specifications for:

D 122–21 T. Imperfections and Tolerances for 60-in. 17¼-oz. Square-Woven Tire Builder Fabric 811

Tentative Definitions of:

D 123–21 T. Terms Relating to Mechanical Fabric 814

E. MISCELLANEOUS SUBJECTS.

Tentative Methods of:

E 3–21 T. Metallographic Testing of Iron and Steel 817

Tentative Definitions of:

E 2–21 T. Terms Relating to Metallography 829

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS.

Standard Specifications for:

C 9–21. Specifications and Tests for Portland Cement 835
D 12–16. Purity of Raw Tung Oil 835

Standard Methods of:

D 22–21. Laboratory Sampling and Analysis of Coal 837

Standard Definitions of:

D 16–15. Terms Relating to Paint Specifications 838
E 2–20. Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys 838

TECHNICAL PAPERS.

PAGE
Impact Tests on Cast Steel—F. C. Langenberg.......... 840
Discussion.......... 850
Comparative Tests of Steels at High Temperatures—R. S. MacPherran.......... 852
Discussion.......... 861
A Test for Shock Strength of Hardened Steel—C. E. Margerum.......... 876
Magnetic Testing of Springs—T. Spooner and I. F. Kinnard.......... 883
Some Failures of Cast-Iron Wheels—H. J. Force.......... 891
Discussion.......... 897
Methods of Casting Manganese-Bronze Test Bars as a Check on Melts of Small Castings—E. H. Dix, Jr.......... 912
Discussion.......... 919
Some Mechanical Properties of Hot-Rolled Monel Metal—P. D. Merica, R. G. Waltenberg, and A. S. McCabe.......... 922
Discussion.......... 939
A Proposed Method of Estimating the Density and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and Concrete—A. N. Talbot.......... 940
Discussion.......... 968
A Study of the Composition of Blast-Furnace Slags Suitable for Concrete Aggregate—L. G. Carmick.......... 976
Discussion.......... 982
A Comparison of the Results of the Slump Test and the Flow Table in the Measurement of the Consistency of Concrete—W. L. Schwalbe.......... 983
Discussion.......... 988
Time of Set of Concrete—Watson Davis.......... 995
Discussion.......... 1007
Variation in the Effect of Rodding Concrete—F. E. Giesecke.......... 1008
Wear Tests of Concrete—D. A. Abrams.......... 1013
Discussion.......... 1035
Testing of Plastic Calcined Magnesite for Use in Oxychloride Cements—M. Y. Seaton.......... 1039
A Method of Determining the Tensile Strength of Porcelain—F. H. Riddle and J. S. Laird.......... 1050
Tests for Soils with Relation to Their Use in the Subgrade of Highways—A. T. Goldbeck and F. H. Jackson.......... 1057
Measurement of Impact—E. B. Smith.......... 1073
Discussion.......... 1081
The Refining of Petroleum—C. K. Francis.......... 1086
Problems Involved in the Development of Specifications for Motor Gasoline—E. W. Dean.......... 1094
Improvements in Apparatus for Testing Petroleum Products—T. G. Delbridge 1100
Stress-Strain Measurements on Films of Drying Oils, Paints and Varnishes—H. A. Nelson.......... 1111
Discussion.......... 1135
The Use of Secondary Reference Standards in Process Problems of Color Measurement—H. S. Busby.......... 1139
Discussion.......... 1147
On Plastic Flow Through Capillary Tubes—E. Buckingham.......... 1154
Discussion.......... 1157

PAGE
A Study of Elastic Viscous Deformation—P. G. Nutting 1162
Discussion 1169
Officers and Members of Executive Committee 1172
Subject Index 1173
Author Index 1190

INSERT PLATES.

I-V. Corrosion Tests of Iron and Steel 110
VI. Corrosion Tests of Iron and Steel 120

SUMMARY OF THE PROCEEDINGS OF THE TWENTY-FOURTH ANNUAL MEETING.

ASBURY PARK, N. J., JUNE 21-24, 1921.

THE TWENTY-FOURTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at the New Monterey Hotel, Asbury Park, N. J., June 21-24, 1921. The following is an analysis of the attendance at the meeting: Members in attendance or represented, 583; guests, 116; total, 699; ladies, 131. The corresponding statistics for the Twenty-third Annual Meeting are: Members in attendance or represented, 589; guests, 133; total, 722; ladies, 143.

FIRST SESSION—TUESDAY, JUNE 21, 10 A. M.

Miscellaneous Committee Reports.

President George S. Webster in the chair.

The minutes of the Twenty-third Annual Meeting were approved as printed.

The President appointed H. E. Diller and T. G. Delbridge as tellers to canvass the vote for officers.

The Secretary-Treasurer presented the recommendation of Committee E-6 on Papers and Publications that in view of the difficult printing situation that confronted the Society during May and June, making it impossible to distribute all committee reports four weeks in advance of the meeting as required by the Society's regulations, this requirement be waived for this year in order that the reports may properly come before the meeting. On motion, this recommendation was approved.

The report of Committee D-5 on Coke was presented by its chairman, A. C. Fieldner. On motion, the recommendation of the committee that the revision of the Standard Methods for Laboratory Sampling and Analysis of Coal (D 22 - 16), published as tentative for one year, be referred to letter ballot of the Society for adoption as standard, was approved.

In pursuance of the recommendation of the committee, it was voted to continue as tentative the Methods for Determination of Fusibility of Coal Ash (D 22 - 19 T).

The report of Committee D-6 on Coke, Richard Moldenke, chairman, was presented by the secretary, A. C. Fieldner. The recommendation of the committee that the revision of the Standard Methods for Laboratory Sampling and Analysis of Coke (D 37 - 18), published as tentative for one year, be referred to letter ballot of the Society for adoption as standard, was approved.

The proposed Tentative Definitions of Terms Relating to Coke were accepted for publication as a tentative standard, with a slight modification in the definition of "Furnace Coke from Beehive Ovens."

The report of Committee D-10 on Shipping Containers, J. A. Newlin, chairman, was presented by the secretary, T. R. C. Wilson. The proposed new General Specifications for 4-One Boxes and Similar Type Boxes recommended by the committee, were accepted for publication as a tentative standard.

The report of Committee D-11 on Rubber Products was then presented by its chairman, F. M. Farmer. The Secretary-Treasurer presented a written minority report by E. A. Barrier, as well as some written discussion of the report by the Bureau of Standards. After further discussion, the following actions were taken on the recommendations of the committee:

The proposed revised Specifications for Fire Hose for Public Fire Department Use, Specifications for Fire Hose for Private Department Use, Specifications for Braided Air Hose, Specifications for Wrapped Air Hose, and Specifications for Rubber Belting were accepted for publication as tentative standards and the present standard specifications for these products were withdrawn.

The Tentative Specifications for Insulated Wire and Cable (D 27 - 16 T) and the Tentative Specifications for Adhesive Insulating Tape (D 69 - 20 T) were continued as tentative with the revisions recommended by the committee, the latter specifications under the title "Specifications for Commercial Adhesive Tape for Electrical Purposes." The chairman called attention to certain additional revisions in the former specifications that had been agreed upon by a conference of Committee B-1 on Copper Wire and Committee D-11 which brings these specifications into satisfactory harmony with the Society's specifications for copper wire in the charge of Committee B-1.

The proposed new Specifications for Rubber Insulating Tape and the proposed new Specifications for Rubber Gloves for Electrical Workers, were accepted for publication as tentative standards.

The recommendation of the committee that the present Standard Specifications for Steam Hose (D 54 - 20) be reduced to a tentative status was, on motion, approved.

The report of Committee D-14 on Screen Wire Cloth, was presented by its chairman, R. W. Woodward, and accepted for publication.

The report of Committee D-7 on Timber was presented by its chairman, Hermann von Schrenk. The proposed revision in the Standard Specifications for Yellow-Pine Bridge and Trestle Timbers (D 10 – 15), recommended by the committee, was slightly modified in presenting the report, the revision being corrected to read as follows:

> "The clauses 'on either end' and 'or else the greater number of rings shall show at least one-third summer wood,' have given rise to a good deal of misunderstanding, and in order to clarify the intent of the specification the committee recomends that for these words there be substituted the words 'on one end or the other,' making the clause read:
>
> "'Dense Southern yellow pine shall show on one end or the other an average of at least six annual rings per inch and at least one-third summer wood, all as measured over the third, fourth and fifth inches on a radial line from the pith.'"

On motion, this revision, clarifying the present wording of the specification, was approved.

The correction of a typographical error in the Tentative Specifications for Structural Douglas Fir (D 23 – 20 T) was approved, and the specifications continued as tentative.

The tellers on the vote for election of officers presented their report, and in accordance therewith the President announced the election of the following officers:

For President, to serve for one year: C. D. Young.

For Vice-President, to serve for two years: Guilliaem Aertsen.

For Members of Executive Committee, to serve for two years: F. R. Baxter, E. D. Boyer, F. M. Farmer, W. H. Fulweiler.

The President requested Past-Presidents W. H. Bixby and J. A. Capp to escort the President-elect to the chair. Mr. Young expressed his appreciation of the honor of being elected to the Presidency of the Society and he pledged his best efforts to advance the Society's activities.

The meeting then adjourned till 3 P. M.

SECOND SESSION—TUESDAY, JUNE 21, 3 P. M.

On Preservative Coatings and Textiles.

Mr. H. A. Gardner in the chair.

The report of Committee D-1 on Preservative Coatings for Structural Materials was presented by its chairman, Allen Rogers.

On motion, the report was accepted, including the following recommendations:

A revision of the Standard Specifications for Purity of Raw Tung Oil (D 12 – 16) was accepted for publication as tentative.

The following specifications and definitions were accepted for publication as tentative standards: Specifications for Purity of Raw Linseed Oil from South American Seed; Specifications for Purity of Boiled Linseed Oil from South American Seed; Specifications for Zinc Oxide; for Leaded Zinc Oxide; for Basic Sulfate White Lead; for Basic Carbonate White Lead; for Red Lead; for Iron Oxide and Iron Hydroxide; and for Ochre; and proposed Definitions of Terms Relating to Paint Specifications.

The proposed revisions in the Standard Test for Flash Point of Volatile Paint Thinners (D 56 – 19) recommended by the committee, were approved and referred to letter ballot of the Society for adoption as standard.

The proposed revised Specifications for Turpentine, printed as tentative for a year, with the modifications recommended by the committee were referred to letter ballot of the Society for adoption as standard, to replace, if adopted, the present standard.[1]

On motion, the recommendation of the committee to withdraw the present Standard Tests for Paint Thinners Other Than Turpentine (D 28 – 17) was approved, provided the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products, recommended in the report of Committee D-2, are accepted.[2]

The following papers were then presented by their authors and discussed:

"The Use of Secondary Reference Standards in Process Problems of Color Measurement," by H. S. Busby.

"Stress-Strain Measurements on Films of Drying Oils, Paints and Varnishes," by Harley A. Nelson.

In the absence of the author, E. Buckingham, a paper "On Plastic Flow Through Capillary Tubes," was presented by W. H. Herschel and discussed.

The report of Committee D-13 on Textile Materials was presented by its chairman, A. E. Jury. On motion, the proposed Tentative Definitions of Terms Relating to Mechanical Fabric, and the proposed Tentative Specifications for Imperfections and Tolerances for 60-in. 17¼-oz. Square-Woven Tire Builder Fabric were accepted for publication as tentative standards.

The meeting then adjourned till 8 P. M.

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[1] Subsequent to the annual meeting, Committee D-1 recommended to the Executive Committee that this action be reversed. As a result of a special letter ballot, canvassed September 15, 1921, the specifications were retained as tentative and the standard specifications withdrawn.—ED.

[2] This Method was accepted at the eighth session of the annual meeting for publication as a tentative standard. See p. 26.

Third Session—Tuesday, June 21, 8 p. m.

Presidential Address and Reports of Administrative Committees.

Past-President J. A. Capp in the chair.

President George S. Webster presented the annual presidential address, entitled "The Influence of the Work of the American Society for Testing Materials upon the Execution of Public Works."

The Secretary-Treasurer presented the annual report of the Executive Committee which, on motion, was accepted.

The report of Committee E-6 on Papers and Publications was then read by the chairman, C. L. Warwick, who called attention, in presenting the report, to the fact that the recommendation in the report, relative to the waiving of the rule regarding four-weeks' advance distribution of committee reports, had been favorably acted upon at the first session. The report was accepted for publication.

The meeting then adjourned till the following morning, and was followed by an informal dance and smoker.

Fourth Session—Wednesday, June 22, 9.30 a. m.

On Cement and Concrete.

President George S. Webster in the chair.

The report of Committee C-2 on Reinforced Concrete was presented by its chairman, Richard L. Humphrey, and accepted for publication.

The Secretary-Treasurer announced on behalf of the Executive Committee that the progress report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete had been formally transmitted to the Executive Committee by the Society's representatives on the Joint Committee, and suggested that Richard L. Humphrey, chairman of the Society's representatives, be invited to present the progress report. On invitation of the chairman, the report was then presented by Mr. Humphrey. It was explained that various portions of the report would be referred to the appropriate standing committees in the Society for consideration within the coming year.

On motion, the report was received and the decision as to further printing left with power to the Executive Committee.

The following papers were then presented and discussed:

"A Proposed Method of Estimating the Density and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and Concrete," by Arthur N. Talbot.

"Time of Set of Concrete," by Watson Davis.

"A Comparison of the Results of the Slump Test and the Flow Table in the Measurement of the Consistency of Concrete," by W. L. Schwalbe, presented, in the absence of the author, by Arthur N. Talbot.

"Variation in the Effect of Rodding Concrete," by F. E. Giesecke.

"Testing of Plastic Calcined Magnesite for Use in Oxychloride Cements," by Max Y. Seaton, presented by C. R. Hill, in the absence of the author.

"Wear Tests of Concrete," by Duff A. Abrams.

The meeting then adjourned till 8 P. M.

FIFTH SESSION—WEDNESDAY, JUNE 21, 8 P. M.

On Road Materials and Concrete Aggregates.

Mr. Cloyd M. Chapman in the chair.

The report of Committee D-4 on Road and Paving Materials was presented by its chairman, A. H. Blanchard. The report was accepted for publication and the following action taken upon the committee's recommendations:

The revisions in the Standard Test for Penetration of Bituminous Materials (D 5 – 16) and in the Standard Method for Determination of Softening Point of Bituminous Materials Other than Tar Products (D 36 – 19) were referred to letter ballot of the Society for adoption as standard.

It was recommended that the title of the Tentative Specifications for Broken Slag for Waterbound Base (D 65 – 20 T) be changed to read "Tentative Specifications for Broken Slag for Waterbound Base and Wearing Course," the specification being continued as tentative. This recommendation was accepted.

The Tentative Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 – 20 T) and the Tentative Test for Quantity of Clay and Silt in Sand for Highway Construction (D 74 – 20 T) were referred to letter ballot of the Society for adoption as standard.

The following were accepted for publication as tentative standards: Method of Test for Ductility of Bituminous Materials; Method of Test for Water in Bituminous Materials; Specifications for Calcium Chloride for Dust Prevention; Specifications for Asphalt Cement; Specifications for Tar Cement for Use Cold in Repair Work (Cut-Back Product); Specifications for Tar for Surface Treatment, Hot Application; Specifications for Tar Cement; Specifications for Coal-

Tar Pitch for Block Filler; and Specifications for Tar for Surface Treatment, Cold Application.

With respect to the specifications for asphalt and tar cements above referred to, it was explained that at the wish of the committee, the Committee on Papers and Publications had agreed to publish these specifications in revised form in which the several grades included in the specifications would appear as separate specifications in a rearranged form.

A paper by A. T. Goldbeck and F. H. Jackson entitled "Tests for Soils with Relation to Their Use in the Subgrade of Highways," was presented by Mr. Jackson.

A paper on "Measurement of Impact," by E. B. Smith, was then presented by its author.

The report of Committee C-9 on Concrete and Concrete Aggregates, Sanford E. Thompson, chairman, was presented by A. T. Goldbeck, secretary. The report was accepted for publication and the following action taken upon the committee's recommendations:

The following were accepted for publication as tentative standards: Methods of Making Compression Tests of Concrete; Method of Test for Organic Impurities in Sands for Concrete; Method of Test for Sieve Analysis of Aggregates for Concrete; Method of Securing Specimens of Hardened Concrete from the Structure; Specifications for Concrete Aggregates.

The Tentative Test for Unit Weight of Aggregate for Cement Concrete (C 29 - 20 T) and the Tentative Method for Making and Storing Specimens of Concrete in the Field (C 31 - 20 T) were referred to letter ballot of the Society for adoption as standard.

A paper by L. G. Carmick, entitled "A Study of the Composition of Blast-Furnace Slags Suitable for Concrete Aggregate," was presented by the author and discussed.

An experimental investigation of the resistance of columns loaded and exposed to fire and to fire and water, conducted jointly by the Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters and the U. S. Bureau of Standards, was described and illustrated by S. H. Ingberg.

The meeting then adjourned till the following morning.

SIXTH SESSION—THURSDAY, JUNE 23, 9.30 A. M.

On Ceramics, Lime and Gypsum.

Past-President Arthur N. Talbot in the chair.

The Secretary-Treasurer presented the following report of the Executive Committee on the invitation to become a charter member of the Federated American Engineering Societies:

REPORT OF EXECUTIVE COMMITTEE
ON
INVITATION TO SOCIETY TO BECOME CHARTER MEMBER
OF THE
FEDERATED AMERICAN ENGINEERING SOCIETIES.

Thursday, June 23, 1921.

A conference of representatives of national, local, state and regional engineering and allied technical organizations, called jointly by Engineering Council and its constituent societies and held in Washington on June 3 and 4, 1920, recommended to the organizations represented the formation of a body to be known as the Federated American Engineering Societies, whose objects it should be "to further the public welfare wherever technical knowledge and engineering experience are involved and to consider and act upon matters of common concern to the engineering and allied technical professions." The Federation was formally organized in November, 1920, at which time twenty-one engineering organizations (seven national and fourteen state, city or regional bodies) had become members of the Federation. The American Society for Testing Materials was represented at this organization meeting and duly received a formal invitation to become a charter member of the Federation. The Executive Committee concluded that the questions involved in the consideration of this invitation were such as to require a decision by the membership of the Society itself at this annual meeting and so advised the Federation.

In accordance with the announcement of the Executive Committee at the annual meeting a year ago, a circular dated December 3, 1920, was mailed to the membership of the Society announcing the organization of the Federation, stating its objects and scope, and transmitting a copy of the Constitution and By-laws of the Federation.

In view of the organization of the Federation, the then existing Engineering Council was formally dissolved on December 31, 1920. The Federation plans to carry on the work of the former Engineering Council, whose general method of procedure has been approved. Some of the subjects then under consideration and upon which the Federation has since been engaged are quoted from the circular mentioned:

1. Serving the public interest by investigation and advice to the public and to governmental and voluntary bodies upon such national problems as involve industrial and economic questions and the suggestion or approval of competent engineering talent for public service.
2. National Department of Public Works.
3. Conservation of labor and of natural resources.
4. Transportation in its various forms, particularly highways.
5. Patents.
6. Uniform licensing and registration laws.
7. Classification and compensation of engineers.
8. Bureau of employment.
9. Technical education.
10. Advice with and assistance to regional, state and local organizations upon their request.

One of the principal activities of the Federation has been the conducting of an Industrial Waste Survey, which has received notice in the technical and public press.

The membership of the Federation consists of national, local, state and regional engineering and allied technical organizations and affiliations. Management is vested in a new American Engineering Council and its Executive Board; the Council being constituted of representatives of member-societies, each society being entitled to one representative for a membership from 100 to 1000, inclusive, and one additional representative for each additional 1000 members or major fraction thereof. The Federation is financed by contributions from the member-societies, national societies contributing annually $1.50 per member, and local, state and regional organizations $1.00 per member.

The Executive Committee has been able to follow the activities of the Federation through the courtesy of its Executive Board, at whose meetings it has been informally represented upon invitation.

In the circular letter above referred to, the Executive Committee solicited letters from members of the Society giving expression of their views of the Federation and the invitation that the Society become a charter member. Although only a comparatively few such communications have been received—thirty-two to be exact—the Executive Committee believes it incumbent to present a brief analysis of these communications. Half of them were in favor of A.S.T.M. membership in the Federation; in some of these no mention was made of approval or otherwise of an increase of dues, while in others it was stated that if necessary the members should be assessed to meet the dues required by membership in the Federation. Of the remaining sixteen communications, six were definitely opposed to A.S.T.M. membership in the Federation on any grounds, while ten were opposed to such membership if it required an increase in dues of the members. In response to a request to the standing committees that this matter be discussed at their spring meetings and any action or comment transmitted to the Executive Committee, seven committees replied to the Executive Committee; five were opposed to A.S.T.M. membership and two were non-committal. The Executive Committee has given due weight to all communications received in arriving at the conclusions and recommendations that follow.

The Executive Committee believes that the stated objects for which the Federation is organized merit the support of engineering organizations and engineers in general; and that the plan of organization if carried out under wise leadership will bring about consolidation and unity of thought and purpose in the engineering profession. In so far as the Society's technical activities are concerned—that is, the development of knowledge of engineering materials and preparation of standard specifications and methods of tests for materials—the Executive Committee can see no marked advantages to be gained by becoming a member of the Federation, especially in view of the Society's representation upon the American Engineering Standards Committee.

Certain activities of the Federation such as, for example, the matter of uniform licensing, registration and compensation of engineers, the Executive Committee feels are so far outside of the province of our Society that we should not be concerned therein.

In so far as the Society's relations with public matters are concerned, which, as the Society develops, will be of more and more importance in the opinion of the Executive Committee, there are obvious advantages to be gained in affiliation with other national engineering and technical societies through a body organized for the objects for which the Federation stands. The Executive Committee understands that the Federation may concern itself with standardization in its broad aspects, and in this direction would seem to lie one of the principal interests of the Society in the work of the Federation, and the strongest appeal to us for membership in the Federation. It has been pointed out that the Federation will be in a better position than any individual society possibly could be to bring engineering matters and their every-day applications prominently before the general public, and the organization of the Federation is such that it will have means of reaching public opinion throughout the country by reason of its connection with local and regional organizations.

The matter of financial support of the Federation is an important one and has also received the careful consideration of the Executive Committee. In the circular issued last December, the Executive Committee stated that on the basis of the financial condition of the Society at that time it was of the opinion that the dues required for membership in the Federation ($1.50 per member) would have to be raised by direct tax on the membership of the Society equivalent to an increase in the dues of that amount. *The Executive Committee is still of that opinion.* In its annual report to the Society presented Tuesday evening, the Executive Committee referred to the necessity of exercising the utmost economy in issuing the 1921 publications. The committee is unanimously of the opinion that the appropriation for dues in the Federation of approximately $4300 (on the basis of the present membership) from income at the present dues could only be done by curtailing some of the work which the Society is organized to do, and the Executive Committee is confident that the members of the Society do not wish to see its activities lessened in any important direction. The Executive Committee is also unanimously of the opinion that it is unwise at the present time to recommend an increase in the dues for this or any other purpose. Accordingly the Executive Committee has unanimously adopted the following resolution:

> *Resolved*, That in the opinion of the Executive Committee the present finances of the Society do not permit the Society to accept membership in the Federated American Engineering Societies at this time.

In accordance with this resolution the Executive Committee offers the following resolution for consideration and adoption by the Society at this annual meeting:

> *Whereas*, The American Society for Testing Materials has received an invitation to become a charter member of the Federated American Engineering Societies; and
>
> *Whereas*, After thorough consideration the Executive Committee, although believing that the stated objects for which the Federation is organized merit the support of engineering organizations and engineers in general, has recommended that the present finances of the Society do not permit the Society to accept membership in the Federation at this time; therefore, be it
>
> *Resolved*, That the American Society for Testing Materials, after consideration of this invitation in annual meeting assembled, regrets to

advise the Federated American Engineering Societies that it is financially unable at this time to accept the invitation to become a charter member of the Federation.

Respectfully submitted on behalf of the Executive Committee,

C. L. WARWICK,
Secretary-Treasurer.

GEORGE S. WEBSTER,
President.

The Secretary-Treasurer then moved the adoption of the resolution at the close of the Executive Committee's report.

The report was discussed by Richard L. Humphrey, who moved that the motion be amended by directing the Executive Committee to refer two questions to letter ballot of the Society: (1) Shall the American Society for Testing Materials accept membership in the Federated American Engineering Societies? and (2) Shall the Executive Committee be instructed to prepare proper amendments to the By-laws providing for an increase in dues to make this possible?

The question was then discussed by Messrs. W. P. Blair, Richard L. Humphrey, L. H. Hart, J. A. Capp, W. H. Bassett, W. M. Kinney, D. K. Boyd, W. H. Bixby, T. A. Randall and the Secretary-Treasurer.

The question being called for, Mr. Humphrey's motion was put to vote of the meeting and lost. The motion of the Secretary-Treasurer was then carried.

Mr. Humphrey then introduced his amendment to the original motion as a separate motion. This motion was lost by a vote of 32 affirmative, 62 negative.

W. M. Kinney then offered the following resolution, which was adopted:

> *Resolved*, That it is the sense of this meeting that at the proper time in its judgment, the Executive Committee give further consideration to the matter of the Society joining the Federated American Engineering Societies.

The following resolutions were adopted by the meeting and telegraphed, respectively, to Prof. Gaetano Lanza and Past-President A. A. Stevenson:

> "The American Society for Testing Materials, assembled in Annual Meeting, learns with profound regret of the illness of Gaetano Lanza, an Honorary Member of the Society and active in its counsels for many years, and sends to him its sincere wishes for the recovery of his health."
>
> "The American Society for Testing Materials, assembled in Annual Meeting, sends hearty greetings to its honored Past-President, A. A. Stevenson, and regrets that his genial countenance is missed in the Amen Corner."

The report of Committee C-3 on Brick was presented by its chairman, H. T. Shelley. On motion of Mr. Shelley, the proposed Tentative Specifications for Clay Sewer Brick, with certain minor modifications recommended by the committee, were accepted for publication as a tentative standard.

The report of Committee C-4, on Clay and Cement Sewer Pipe, was presented by the chairman, Rudolph Hering, and accepted for publication.

In response to an inquiry of the Secretary-Treasurer, relating to the proposed revised definitions of the terms "clay," "fire clay" and "shale," that were being considered jointly by Committee C-4 and Committee C-6 on Drain Tile, Mr. Hering stated that Committee C-4 had agreed to adopt the definitions of those terms proposed by Committee C-6 and appearing in the Standard Specifications for Drain Tile (C 4 - 16). It was then voted to change the definitions in the Standard Specifications for Clay Sewer Pipe (C 13 - 20) accordingly.

The report of Committee C-6 on Drain Tile, Anson Marston, chairman, was presented by the vice-chairman, Arthur N. Talbot, the Secretary-Treasurer occupying the chair during the presentation of the report. On motion of Mr. Talbot, the proposed revisions in the Standard Specifications for Drain Tile (C 4 - 16), published as tentative for one year, were referred to letter ballot of the Society for adoption as standard.

The report of Committee C-7 on Lime was presented by its chairman, H. C. Berry. The following action was taken on the recommendations of the committee:

The proposed Tentative Specifications for Quicklime for Structural Purposes and the proposed Tentative Specifications for Hydrated Lime for Structural Purposes, were accepted for publication as tentative standards and the present standards of the Society covering those materials were withdrawn.

The Tentative Methods of Chemical Analysis of Lime, Limestone and Hydrated Line (C 25 - 19 T) were continued as tentative in their revised form as recommended by the committee.

In presenting the report, the chairman explained that certain tests on effect of hydrated lime on concrete mixtures had inadvertently been omitted, and it was voted to include these tests in the report as printed in the Proceedings. On motion, the report as thus revised was accepted.

The report of Committee C-8 on Refractories, was presented by W. H. Fulweiler, secretary. The following action was taken on the recommendations of the committee:

The Tentative Method for Ultimate Chemical Analysis of Chrome Ores and Chrome Brick (C 18 – 20 T) was referred to letter ballot of the Society for adoption as standard.

The proposed Tentative Method of Test for Resistance of Fire-Clay Brick to Spalling Action was accepted for publication as a tentative standard.

The Tentative Test for Slagging Action of Refractory Materials (C 17 – 19 T) was continued as tentative.

The report of Committee C-10 on Hollow Building Tile, was presented by its chairman, W. A. Hull. Mr. Hull moved the acceptance of the proposed Tentative Specifications for Clay Hollow Building Tile, for publication as a tentative standard, with the understanding that the following footnote, recommended by the committee, would be added under the heading "physical test requirements":

> "Tests now under way may modify the physical test requirements here given, and until further data are available they should be taken as strictly tentative."

At the suggestion of D. K. Boyd, the requirement for scoring tile (Section 32) was revised to apply only to tile intended for stucco or mortar.

Mr. Hull's motion was then carried and the specifications, as revised, accepted for publication as tentative.

Mr. Hull then moved the acceptance for publication as tentative of the proposed Definitions of Terms Relating to Hollow Tile, with the following revised definitions recommended by the committee:

Hollow Tile.—Hollow burned clay building units with parallel cells.

Book Tile.—Hollow tile, resembling a book in shape, designed to fill space between supporting members of roof or similar structures and having tongue and groove edges.

In Section 5 (*b*) add the word "tile" after "furring."

W. M. Kinney moved to amend the motion by inserting the word "clay" between the words "hollow" and "tile" in the definition of Hollow Tile in Section 1. This amendment was carried by a vote of ten affirmative, seven negative.

Mr. Hull's motion, as amended, was then carried and the definitions, as amended, were accepted for publication as a tentative standard.

The definitions of "clay," "fire clay" and "shale" were also discussed, particularly with regard to other definitions of these terms that appear elsewhere in the Society's publications. It was explained that the definitions of these terms are under consideration by Committee E-8 on Nomenclature and Definitions and it was suggested by the

Secretary-Treasurer that this fact might well be pointed out in the form of an editorial note wherever these definitions appear. On motion of R. C. Purdy it was voted to insert suitable editorial notes as suggested.

The report of Committee C-11, on Gypsum, was presented by the chairman, W. E. Emley. The following action was taken on the recommendations of the committee:

The Tentative Specifications for Gypsum (C 22 – 20 T) and the Tentative Specifications for Calcined Gypsum (C 23 – 20 T) were continued as tentative in their proposed revised form.

The Tentative Specifications for Gypsum Plasters (C 28 – 20 T) as revised were referred to letter ballot of the Society for adoption as standard.

The proposed Tentative Specifications for Gypsum Plaster Board and for Gypsum Wall Board, and for Gypsum Plastering Sand, were accepted for publication as tentative standards.

The revised Tentative Methods of Testing Gypsum and Gypsum Products (C 26 – 20 T) and the revised Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 16 T) were accepted for publicaton as tentative.

The meeting then adjourned till 3 P. M.

SEVENTH SESSION—THURSDAY, JUNE 23, 3 P. M.

On Testing and Nomenclature.

President-elect C. D. Young in the chair.

The report of Committee E-1 on Methods of Testing, J. A. Capp, chairman, was presented by the secretary, C. L. Warwick.

The recommendations of the committee that the title of the Standard Methods of Testing (E 1 – 18) be changed to read "Standard Methods of Mechanical Testing of Metallic Materials," and that the portion of these Methods devoted to metallographic testing of metals be withdrawn (provided the Tentative Methods proposed by Committee E-4 on Metallography are accepted), were approved.

The report of Committee E-4 on Metallography, was then presented by the chairman, W. H. Bassett. The proposed Tentative Methods of Metallographic Testing of Iron and Steel and the proposed Tentative Definitions of Terms Relating to Metallography were accepted for publication as tentative standards.

The report of Committee E-8 on Nomenclature and Definitions was read by the chairman, Cloyd M. Chapman, and accepted.

The report of Committee D-9 on Electrical Insulating Materials, was then presented by its chairman, F. M. Farmer. The proposed Tentative Methods of Testing Insulating Varnishes, the proposed Tentative Methods of Testing Porcelain, and the proposed Tentative Methods of Testing Transformer and Switch Oils, were accepted for publication as tentative standards.

The chairman stated that the committee had reconsidered its recommendation that the Tentative Tests for Molded Insulating Materials (D 48 – 17 T), revised as indicated in the report, be referred to letter ballot for adoption as standard, and now recommended that these Tests in their revised form be continued as tentative. On motion, this recommendation was approved.

The Secretary-Treasurer read the following telegram received from Prof. Gaetano Lanza:

> "Gaetano Lanza thanks the American Society for Testing Materials for its expression of sympathy and good wishes for him in his illness and will look forward with pleasant anticipation to the time when he may again be present at its meetings."

In the absence of the authors, F. H. Riddle and J. S. Laird, their paper on "A Method of Determining the Tensile Strength of Porcelain" was summarized by the Secretary-Treasurer and discussed.

A paper by Thomas Spooner and I. F. Kinnard on "Magnetic Testing of Springs," was then presented by Mr. Spooner and discussed.

In the absence of P. G. Nutting his paper, entitled "A Study of Elastic Viscous Deformation," was presented in abstract by Mr. Spooner and discussed.

The meeting then adjourned till 8 P. M.

EIGHTH SESSION—THURSDAY, JUNE 23, 8 P. M.

On Petroleum Products.

Past-President W. H. Bixby in the chair.

In the absence of the chairman, C. P. Van Gundy, the report of Committee D-2 on Petroleum Products and Lubricants was presented by the secretary, K. G. Mackenzie.

In presenting the report Mr. Mackenzie stated that the committee had held a meeting on the preceding day at which a number of minor modifications in the tentative methods submitted with its report had been unanimously agreed upon, affecting principally certain details involved in the several thermometer specifications in these methods.

The following action was taken upon the recommendations of the committee in their revised form:

The proposed revision of the Test for Free Acid in the Standard Tests for Lubricants (D 47 – 18) was referred to letter ballot of the Society for adoption as standard.

The present Standard Cloud and Pour Tests and Cold Test were withdrawn from the Standard Tests for Lubricants (D 47 – 18) and the proposed revised Tentative Methods of Test for Cloud and Pour Points of Petroleum Products, revised as recommended by the committee, were accepted for publication as a tentative standard.

The proposed Tentative Method of Test for Distillation of Gasolene, Naphtha, Kerosene and Similar Petroleum Products, in revised form as recommended by the committee, was accepted for publication as a tentative standard. Attention was called to the fact that at an earlier session,[1] the Society had acted favorably upon the recommendation of Committee D-1 on Preservative Coatings that the present Distillation Test for Paint Thinners be withdrawn, provided the Tentative Method of Test for Distillation, recommended by Committee D-2 was accepted by the Society.

The following proposed methods of test in revised form as recommended by the committee were, on separate motion, accepted for publication as tentative standards: Test for the Melting Point of Paraffin Wax; Flash and Fire Points by means of Open Cup; and Test for Flash Point by Means of the Pensky-Martens Closed Tester.

The following proposed methods of test were accepted without revision for publication as tentative standards: Test for Viscosity of Fuel Oils and Other Oils of Similar Viscosity; Test for Sulfur in Naphthas and Illuminating Oils; Test for Precipitation Number of Lubricating Oils; Test for Water in Petroleum Products; Test for Water and Sediment in Petroleum Products by Means of Centrifuge.

The proposed Tentative Method of Test for Saponification Number, was accepted for publication as a tentative standard. The question of title of this method was discussed and on motion left with power to Mr. Mackenzie and the Secretary-Treasurer.

Mr. Mackenzie stated that the committee had made some important corrections in the proposed Tentative Method of Test for Detection of Sulfur and Corrosive Sulfur Compounds in Petroleum Products, and submitted on behalf of the committee the following revised methods under the title "Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Petroleum Products:

"1. This method of test is applicable for the detection of free sulfur and corrosive sulfur compounds in oil.

"2. (*a*) A clean strip of mechanically polished pure sheet copper about ½ in.

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[1] See p. 14.

wide and 3 in. long shall be put into a sample of the oil contained in a clean test tube about half the length of the copper strip being submerged. The test tube shall then be closed with a stopper (venting where volatile materials are being tested) and left to stand over night at a temperature of 150° F.

"(*b*) At the end of this time the copper strip shall be removed and washed free from oil with gasoline. It shall then be compared with a similar strip of copper freshly polished in a similar manner.

"3. If free sulfur or corrosive sulfur compounds are present in the oil the copper test strip will appear discolored when compared with the freshly cleaned copper."

On motion, the method of test, as revised, was accepted for publication as a tentative standard.

Mr. Mackenzie called attention to the favorable action of Committee D-2 upon the proposed revised Standard Method of Test for Flash Point of Volatile Flammable Liquids recommended for adoption as standard in the report of Committee D-1 and favorably acted upon by the Society at an earlier session.[1]

Mr. Mackenzie stated that the committee wished to withdraw the report of Sub-Committee XV on Sampling and Gaging in order that further opportunity might be given to get this matter into more satisfactory form. On motion, this recommendation was approved.

The reports of Sub-Committees I on Petrolatum, IV on Grease and VI on Color were presented briefly by their respective chairmen.

The following papers were then presented by their authors and discussed:

"The Refining of Petroleum," by C. K. Francis.

"Improvements in Apparatus for Testing Petroleum Products," by T. G. Delbridge.

"Problems Involved in the Development of Specifications for Motor Gasoline," by E. W. Dean.

The meeting then adjourned until the following morning, and the session was concluded by the presentation of a motion picture on the "Story of Petroleum," made available through the courtesy of the U. S. Bureau of Mines.

NINTH SESSION—FRIDAY, JUNE 24, 9.30 A. M.

Steel and Wrought Iron.

Vice-President G. K. Burgess in the chair.

The report of Committee A-1, on Steel, was presented by its chairman, F. M. Waring. Mr. Waring stated that at a meeting of the committee, held on Wednesday, June 22, the committee had reconsidered the proposed new Tentative Specifications for Carbon-Steel Rails (Special Quality Requirements) and had unanimously voted to withdraw these specifications and to omit all reference to them in its report.

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[1] See p. 14.

The following actions were taken upon the committee's recommendations:

The Tentative Specifications for Commercial Bar Steels (A 80 – 20 T), revised as indicated in the report, were referred to letter ballot of the Society for adoption as standard.

The proposed revised Specifications for Welded and Seamless Steel Pipe, as appended to the report, were referred to letter ballot for adoption as standard, to supersede, if adopted, the present Standard Specifications for Welded Steel Pipe (A 53 – 18).

The revisions proposed in the following tentative standards were approved and the specifications as thus revised continued as tentative: Tentative Specifications for Tie Plates (A 67 – 18 T), Tentative Specifications for Low-Carbon Steel Track Plates (A 76 – 18 T), Tentative Specifications for Steel Plates for Forge Welding (A 78 – 20 T), Tentative Specifications for Boiler and Firebox Steel for Stationary Service (A 70 – 18 T), and Tentative Specifications for Carbon Tool Steel (A 71 – 20 T).

The following new specifications were accepted for publication as tentative standards: Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement and Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes, the latter with the understanding that the explanatory note in the body of the committee report, relating to the basis on which tubes are gaged for thickness in these specifications, would be included with the specifications.

The recommendations of the committee with respect to the phosphorus and sulfur note that now appears in fourteen A.S.T.M. specifications were explained by Mr. Waring, and were approved and referred to letter ballot for adoption, as follows:

> Remove the note on Phosphorus and Sulfur allowances from all of the fourteen specifications in which it now appears;
>
> Increase the maximum sulfur allowance 0.01 per cent in the following specifications: Specifications for Structural Steel for Locomotives (A 10 – 16); Specifications for Structural Steel for Cars (A 11 – 16); Specifications for Structural Steel for Ships (A 12 – 16); and Specifications for Steel Castings (A 27 – 16);

Increase the maximum phosphorus allowance 0.01 per cent in acid steel in the following specification: Specifications for Steel Castings (A 27 - 16).

The proposed revisions in the following standards were then referred to letter ballot of the Society for adoption as standard:

For Open-Hearth Steel Girder and High Tee Rails (A 2 - 12);
For Quenched High-Carbon-Steel Splice Bars (A 49 - 15);
For Quenched Carbon-Steel Track Bolts (A 50 - 16);
For Steel Track Spikes (A 65 - 18);
For Steel Screw Spikes (A 66 - 18);
For Low-Carbon-Steel Splice Bars (A 3 - 14);
For Quenched Alloy-Steel Track Bolts (A 51 - 16);
For Structural Steel for Bridges (A 7 - 16);
For Structural Nickel Steel (A 8 - 16);
For Structural Steel for Buildings (A 9 - 16);
For Structural Steel for Locomotives (A 10 - 16);
For Structural Steel for Cars (A 11 - 16);
For Rivet Steel for Ships (A 13 - 14);
For Carbon-Steel Bars for Railway Springs (A 14 - 16);
For Carbon-Steel Bars for Railway Springs with Special Silicon Requirements (A 68 - 18);
For Carbon-Steel Bars for Vehicle and Automobile Springs (A 58 - 16);
For Silico-Manganese-Steel Bars for Automobile and Railway Springs (A 59 - 16);
For Chrome-Vanadium-Steel Bars for Automobile and Railway Springs (A 60 - 16);
For Billet-Steel Concrete Reinforcement Bars (A 15 - 14);
For Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for Forgings (A 17 - 18);
For Carbon-Steel and Alloy-Steel Forgings (A 18 - 18);
For Quenched-and-Tempered Carbon-Steel Axles, Shafts, etc., for Locomotives and Cars (A 19 - 18);
For Quenched-and-Tempered Alloy-Steel Axles, Shafts, etc., for Locomotives and Cars (A 63 - 18);
For Carbon-Steel Forgings for Locomotives (A 20 - 16);
For Cold-Rolled Steel Axles (A 22 - 16);
For Steel Castings (A 27 - 16);
For Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 - 18);

For Automobile Carbon and Alloy Steels (A 29 – 18);
For Boiler and Firebox Steel for Locomotives (A 30 – 18);
For Boiler Rivet Steel (A 31 – 14).

Mr. Waring then explained that the committee, at its meeting on Wednesday, had unanimously adopted certain revisions in the heat treatment clauses of four forging specifications, in order to clarify the present requirement that "the forgings shall be allowed to become cold after forging." It was explained that if this were allowed in certain cases it would be detrimental to certain classes of forgings and might cause the entire loss of the forging. The committee, therefore, proposed the following revisions in the four specifications affected:

Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (A 18 – 18).

Section 6.—Change to read as follows:

"6. Heat treatment, if required, shall consist of either annealing or quenching and tempering, as specified.

"(*a*) The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an 'annealing charge'), and allowed to cool uniformly.

"(*b*) The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a 'quenching charge'), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or 'drawing back' (a group thus reheated being known as a 'tempering charge'), and allowed to cool uniformly."

Standard Specifications for Quenched-and-Tempered Carbon-Steel Axles, Shafts, and other Forgings for Locomotives and Cars (A 19 – 18).

Section 6.—Change to read the same as Section 6 (*b*) of Specifications A 18 – 18 above.

Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts and other Forgings for Locomotives and Cars (A 63 – 18).

Section 6.—Change to read the same as Section 6 (*b*) of Specifications A 18 – 18 above.

Standard Specifications for Carbon-Steel Forgings for Locomotives (A 20 – 16).

Section 6.—Change to read the same as Section 6 (*a*) of Specifications A 18 – 18 above.

On motion of Mr. Waring, these revisions were referred to letter ballot of the Society for adoption as standard.

The report of the committee was then accepted for publication in its revised form.

The report of Committee A-4 on Heat Treatment of Iron and Steel, H. M. Boylston, chairman, was, in the absence of the chairman, presented by J. H. Hall, secretary. The proposed revisions in the Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects (A 35 – 11) were referred to letter ballot of the Society for adoption.

A question raised by R. W. Woodward regarding the omission from the list of physical properties of the terms "proportional limit" and "yield point," was referred to the committee for consideration, and the report was, on motion, accepted for publication.

The Secretary-Treasurer then read a letter from Past-President A. A. Stevenson, expressing his appreciation of the thoughtful remembrance of the Society in telegraphing their regret at his absence from the meeting and his best wishes for a most successful convention.

A paper by F. C. Langenberg on "Impact Tests on Cast Steel" was, in the absence of the author, presented by J. H. Hall and discussed.

A paper entitled "Comparative Tests of Steels at High Temperatures," was presented by the author, R. S. MacPherran, and discussed.

A paper on "A Test for Shock Strength of Hardened Steel," was read by the author, C. E. Margerum.

The report of Committee A-2 on Wrought Iron was presented by its chairman, H. E. Smith. Mr. Smith stated that the committee had held a meeting on Thursday, June 24, and had adopted certain modifications in its report as preprinted, to which he referred at the appropriate places. The following action was taken on the committee's recommendations as revised:

The proposed revised Specifications for Welded Wrought-Iron Pipe, in the form as appended to the report of the committee, were referred to letter ballot of the Society for adoption as standard.

The proposed revisions in the Standard Specifications for Lap-Welded Charcoal-Iron Boiler Tubes for Locomotives (A 38 – 18) were referred to letter ballot of the Society for adoption as standard.

Mr. Smith then stated that in addition to the revision recommended in the committee's report in Section 4 of Standard Specifications for Engine-Bolt Iron (A 40 – 18) and the revision in Section 1 proposed by the committee at the annual meeting a year ago, the committee, at its recent meeting, unanimously voted to modify the lower limit of tensile requirements to provide for the larger size of bars that are now being ordered to these specifications and for which the specifications were not originally adapted. The committee accordingly recommended that Section 3 (*a*) of these specifications be changed to read as follows:

"3 (*a*) The iron shall conform to the following requirements as to tensile properties:

	Sectional Area $1\frac{1}{4}$ sq. in. and under.	Sectional Area Over $1\frac{1}{4}$ sq. in. to and including 4 sq. in.	Sectional Area over 4 sq. in.
Tensile strength, lb. per sq. in.	49 000 – 53 000	47 000 – 53 000	47 000 – 53 000
Yield point, min., lb. per sq. in.	0.6 tens. str.	0.55 tens. str.	0.5 tens. str.
Elongation in 8 in., min., per cent	25	25	25
Reduction of area, min., per cent	40	40	40

the section as revised thus including the present and proposed requirements of Section 4 and making that section unnecessary."

On motion, this revision was approved and referred to letter ballot of the Society for adoption as standard.

The proposed Tentative Specifications for Iron and Steel Chain were accepted for publication as a tentative standard and the present standard specifications (A 56 – 18) were withdrawn.

Regarding its recommendation that the Tentative Specifications for Extra-Refined Wrought-Iron Bars (A 79 – 19 T) be referred to letter ballot of the Society for adoption as standard, Mr. Smith stated that at its meeting on Thursday the committee had voted to make the following revision in the requirement for yield point, similar to those proposed for the Specifications for Engine Bolt Iron (A 40 – 18) and for the same reasons:

In Section 4 (*a*) change the requirements for minimum yield point to read as follows:

Sectional Area $1\frac{1}{4}$ sq. in. and under	0.6	tens. str.
Sectional Area over $1\frac{1}{4}$ sq. in. to and including 4 sq. in.	0.55	" "
Sectional Area over 4 sq. in.	0.5	" "

On motion, this revision was accepted and the specifications as thus revised were referred to letter ballot of the Society for adoption as standard.

The Tentative Definitions of Terms Relating to Wrought-Iron Specifications (A 81 – 20 T) were referred to letter ballot of the Society for adoption as standard.

The following revision in the Standard Specifications for Staybolt Iron (A 39 – 18), proposed a year ago and published as tentative, was referred to letter ballot of the Society for adoption as standard:

Section 10.—Change to read as follows by the addition of the italicized figures and the omission of the figures in brackets:

"The bars shall be truly round within 0.01 in. and shall not vary more than [0.005] *0.01* in. above, nor more than [0.01] *0.005* in. below the specified size."

The proposed Specifications for Merchant Bar Iron were accepted for publication as a tentative standard with one correction, the insertion of the word "reworked" before "mixture" in Section 1.

The proposed Specifications for Hollow Staybolt Iron were accepted for publication as a tentative standard.

The meeting then adjourned till 8 P. M.

TENTH SESSION—FRIDAY, JUNE 24, 8 P. M.

Cast Iron, Corrosion and Non-Ferrous Metals.

President George S. Webster in the chair.

The report of Committee A-3 on Cast Iron was presented by its chairman, Richard Moldenke.

In offering for adoption as tentative the proposed revised Specifications for Cast-Iron Car Wheels, and the withdrawal of the present Standard Specifications for Car Wheels, the chairman stated that at a meeting of the committee it had been voted to add the following chemical requirements to the specifications:

"The wheels shall conform to the following requirements as to chemical composition:

Combined carbon		0.50 – 0.85	per cent
Silicon		0.45 – 0.75	"
Manganese		0.50 – 0.75	"
Phosphorus	not over	0.40	"
Sulfur	" "	0.18	"

"The minimum percentage of manganese shall be not less than three times the sulfur content.

"It is desired that the phosphorus content shall not exceed 0.30 per cent.

"Drillings for chemical analysis shall be taken from drill hole bored entirely through the back double plate of the wheel between core legs."

Before calling for action upon the committee's recommendations, the chair suggested that H. J. Force present his paper entitled "Some Failure of Cast-Iron Wheels."

Following the presentation of this paper by Mr. Force, the report of Committee A-3 and Mr. Force's paper were discussed jointly.

The proposed Tentative Specifications for Cast-Iron Car Wheels, revised as recommended by the committee, were then accepted for publication as a tentative standard.

The chair then called for the report of the Entertainment Committee, E. D. Boyer, chairman.

Mr. Boyer stated that the fifth annual Golf Tournament and the first Tennis Tournament had been successfully held that afternoon and on behalf of the committee he awarded the following prizes:

GOLF TOURNAMENT.

For Low Score for the Course:

The American Society for Testing Materials Championship Cup and medal	E. D. Boyer, New York City.

For the Lowest Net Score:

First Prize	W. D. Kerlin, Camden, N. J.
Second Prize	T. A. Hicks, Catasauqua, Pa.
Third Prize	C. S. Bilyeu, New York City.

For the winner of the "Blind Handicap":

A silver cup	A. E. Thurber, Kenwood, N. Y.

Monel Metal Club Heads Awarded for:

Nearest Pin 13th Hole	R. L. Hayes, Philadelphia, Pa.
Nearest Pin 18th Hole	L. E. Thomas, Reading, Pa.
Best Total Gross Score, Holes 5, 8, 12, 13	E. E. Hughes, Franklin, Pa.
" " " " First 9 holes	J. H. Parker, Reading, Pa.
" " " " Second 9 holes	L. L. Shober, Jr., Reading, Pa.

TENNIS TOURNAMENT.

First Prize	A. G. Blakeley, Pottsville, Pa.
Second Prize	Thomas Spooner, Pittsburgh, Pa.

The report of Committee A-5 on Corrosion of Iron and Steel, S. S. Voorhees, chairman, was, in the absence of Mr. Voorhees, presented by A. S. Cushman, acting chairman. Mr. Cushman called attention to a correction in the sixth paragraph in the report by which the word "steel" wherever it appears in that paragraph is to be changed to read "sheets." With this correction and after some discussion, the report was accepted for publication in the Proceedings.

The report of Committee B-1 on Copper Wire was presented by its chairman, J. A. Capp. With the correction of two errors referred to in the report, the Tentative Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 – 19 T) were referred to letter ballot of the Society for adoption as standard.

The proposed revisions in the Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (B 8 – 16) were referred to letter ballot of the Society for adoption as standard.

The report of Committee B-2 on Non-Ferrous Metals and Alloys, William Campbell, chairman, was, in the absence of the chairman, presented by the secretary, P. D. Merica. The following actions were taken upon the committee's recommendations:

The proposed new Specifications for Nickel were accepted for publication as a tentative standard.

Mr. Merica stated that at a meeting held the preceding day the committee had reconsidered the proposed revisions in the Tentative Specifications for Pig Lead (B 29 – 20 T) recommended in the preprint of the committee's report and had referred these revisions back to the appropriate sub-committee for further consideration. On motion, these specifications were continued as tentative without revision.

The following tentative specifications were, on motion, referred to letter ballot of the Society for adoption as standard: Tentative Specifications for Sheet High Brass (B 36 – 20 T); Tentative Specifications for Bronze Bearing Metals for Turntables (B 22 – 18 T); Tentative Specifications for Bronze Bearing Metals in Ingot Form (B 31 – 19 T).

Regarding the recommendations of the committee that the table of physical properties, included as an appendix to the latter specifications, be revised to give compression yield point on cylindrical specimens of 1 sq. in. in sectional area and 3 in. high, determined as defined in Standard Methods of Testing, the revised figures to be supplied by Committee E-1 on Methods of Testing, it was agreed, on recommendation of the Secretary-Treasurer, that in view of the practical impossibility of Committee E-1 being able to supply these figures in time for publication in the Book of Standards the present figures be permitted to stand, and an editorial footnote inserted explaining that revision along the lines indicated by Committee B-2, is under consideration by Committee E-1.

The correction of an error in the Specifications for Free-Cutting Brass Rod for Use in Screw Machines (B 16 – 18), referred to in the committee's report, was authorized.

The proposed revisions in the Tentative Specifications for Brass Ingot Metal for Sand Castings (B 30 – 19 T) recommended by the committee were approved, and the specifications continued as tentative.

The Tentative Specifications for Solder Metal (B 32 – 19 T) were referred to letter ballot of the Society for adoption as standard, while the Tentative Specifications for White Metal Bearing Alloys (B 23 - 18 T) were continued as tentative in pursuance of the committee's recommendation.

Mr. Merica offered the following revision in the Tentative Specifications for Non-Ferrous Alloys for Railway Equipment (B 17 - 18 T) which had been unanimously agreed upon at a meeting of the committee held since its report was preprinted. This revision provides for an additional alloy designated as "Phosphor Bronze." The necessary changes in the specifications are:

In Section 1 (*b*) before "Bearing Metal No. 1," insert the paragraph:

"***Phosphor Bronze***, for connecting-rod bearings, bushings, eccentric straps, crosshead gibs, and miscellaneous bushings, in place of Bearing Metal No. 1, when specifically covered in the contract."

In the table in Section 2 (*a*) on Chemical Composition, insert the following new requirements for Phosphor Bronze and revise the requirements for Bearing Metal No. 1 to read as indicated:

Alloy.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, max., per cent.	Iron, max., per cent.	Antimony, per cent.	Phosphorus, per cent.	Sulfur, max., per cent.	Arsenic max., per cent.	Total Impurities, including Zinc, max., per cent.
Phosphor Bronze.....	remainder	9 - 11	8 - 11	0.75	0.25	0.25*a*	0.7 - 1.0	...	....	1.0
Bearing Metal No. 1..	remainder	9 - 11	9 - 11	1.50	0.25	0.25*a*	....	...	....	2.0

Delete Footnote *b* and insert a subscript letter "a" after the phosphorus requirement 0.02 for Bell Metal.

On motion, this revision was accepted, subject to subsequent approval of the committee by letter ballot vote, and the specifications continued as tentative.

Referring to the recommendation of the committee that the Tentative Methods for Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (B 18 - 20 T) be referred to letter ballot for adoption as standard, Mr. Merica called attention to the following corrections in this Method in addition to those mentioned in the committee's report:

1. In Part II of the Methods on "Rapid Method for Control Work," replace the present method (*a*) "Determination of Lead" by the following:

"In a covered 300-cc. Erlenmeyer flask dissolve 1 g. of the alloy in 20 cc. of H_2SO_4 (sp. gr. 1.84); heat the solution nearly to boiling until the metal is completely decomposed and the $PbSO_4$ is white (this may take ½ hour or more) and finally boil for several minutes. Allow to cool, but not below 60° C., and then add slowly 50 cc. of water while the solution is agitated. Heat to boiling for several minutes in order to insure complete solution of antimony sulfate. Allow the $PbSO_4$ to settle out until the solution is clear, not letting the temperature fall below 60° C. If the liquid does not clear quickly it must be heated longer. When clear pour the solution through a weighed porcelain Gooch crucible with asbestos mat, decanting the solution as completely as possible without allowing more than a very small amount of $PbSO_4$ to go over into the crucible. Now add 10 cc. more of H_2SO_4 (sp. gr. 1.84) to the $PbSO_4$ in the original flask, and boil for several minutes. Cool, add slowly 30 cc. of water, and again heat to boiling for a few minutes; allow the solution to cool to about 60° C. and completely transfer the $PbSO_4$ to the Gooch crucible. Wash with lead acid, retaining the filtrate and these washings for the copper determination. Remove the beaker containing these solutions and wash out the lead acid with dilute alcohol; set the Gooch crucible inside a porcelain crucible; dry and ignite for five minutes at the full heat of a Tirrill burner; cool and weigh as $PbSO_4$, which contains 68.29 per cent lead."

2. At the end of the Methods under Notes[1] add the following note:

"For accurate work it is preferable to reduce and titrate the solution of tin in an atmosphere of CO_2."

On motion, these revisions were approved and the Methods as thus revised referred to letter ballot of the Society for adoption as standard.

The proposed Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys and Methods of Chemical Analysis of Nickel were accepted for publication as tentative standards.

The Tentative Specifications for Light Aluminum Casting Alloys (B 26 – 19 T) were referred to letter ballot of the Society for adoption as standard.

The following revision in the Standard Specifications for Copper Bars for Locomotive Staybolts (B 12 – 18) proposed by the committee a year ago was, on motion, referred to letter ballot of the Society:

Section 9.—Change to read as follows by the addition of the figures in italics and the omission of the figures in brackets:

"The bars shall be truly round within 0.01 in. and shall not vary more than [0.005] *0.01* in. above nor more than [0.01] *0.005* in. below the specified size."

The report of the committee as revised was then accepted for publication in the Proceedings.

A paper by E. H. Dix, Jr., on "Methods of Casting Manganese-Bronze Test Bars as a Check on Melts of Small Castings" was, in the absence of the author, presented by J. L. Jones and discussed.

A paper on "Some Mechanical Properties of Hot-Rolled Monel Metal," by P. D. Merica, R. G. Waltenberg and A. S. McCabe, was presented by Mr. Merica and discussed.

The presentation of this paper concluded the regular order of business and the chair asked if there was any miscellaneous business.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 598 (1920).

The Secretary-Treasurer announced the final attendance at the meeting,[1] stating that the number of members present and represented was only 6 below that of last year, and that the total registration was only 35 less than a year ago; and expressing his gratification at this remarkable showing in view of present conditions.

The President then expressed his high appreciation of the honor of having served as President of the Society and thanked the members of the Society, the members of the Executive Committee and the Secretary for their cooperation and helpful assistance in the performance of his duties.

There being no further business, President Webster then declared the meeting of the American Society for Testing Materials adjourned *sine die.*

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[1] See p. 11.

AMERICAN SOCIETY FOR TESTING MATERIALS.

ORGANIZED IN 1898.
INCORPORATED IN 1902.

PROCEEDINGS.

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

THE INFLUENCE OF THE WORK OF THE AMERICAN SOCIETY FOR TESTING MATERIALS UPON THE EXECUTION OF PUBLIC WORKS.

ANNUAL ADDRESS BY THE PRESIDENT, GEORGE S. WEBSTER.
June 21, 1921.

In reviewing the events during the time that I have been engaged in Municipal Engineering, it is realized that of the great changes that have taken place, none have been so important as the increasing control over the materials entering into the construction of public work. The increased efficiency in inspecting and testing these materials has made possible more rigid specifications for their purchase and the consequent improvement in their quality. In the late seventies when I began my engineering career, the importance of testing materials, especially metals, was recognized as a control of quality, and the manufacturer was beginning to appreciate the importance of factory or mill tests as a means of securing uniformity of product, with the consequent increased economy in cost of manufacture. In all these efforts it was early apparent that standard methods of testing were necessary, especially as a basis for standard specifications.

In 1882 a call was issued for a preliminary meeting in Munich "to devise means for promoting a greater uniformity in the methods for testing materials." Subsequent conferences were held, and in 1895 the International Association for Testing Materials was formed. In 1890 the French government appointed a Commission to report on "Methods for Testing the Materials of Construction." This Commission was identified with the Congresses of the International Association for Testing Materials and its report was an important and valuable contribution to the advancement of the art of testing the materials of construction.

In the early nineties the difficulties in obtaining materials of a specified quality were so great that I requested Mr. Richard L. Humphrey to undertake the work of creating a Municipal Testing Laboratory in the City of Philadelphia, in which control tests could be made on the materials delivered for use in public work. This laboratory at first tested cement, but as time went on other materials were tested until to-day it is a very important adjunct in municipal work in Philadelphia and its activities cover the inspection and testing of a wide range of building materials. The laboratory began with cement, which was one of the first materials for which a standard was adopted by this Society, and systematic tests were inaugurated of the material that was delivered for use, and based upon the results of these tests, the requirements of the specifications for cement were gradually raised until in a few years they were the most rigid in the country. The results of its published tests and the specifications adopted showed the inadequacy of the American Society of Civil Engineers' rules for testing cement, recommended by a committee of that Society in 1885, and the evident necessity for a revision, which led to the appointment of a committee by that Society for that purpose.

It is interesting in this connection to note that for over a year the headquarters of the American Section of the International Association for Testing Materials, organized on June 16, 1898, were in the testing laboratory of the City of Philadelphia. At the time of the formation of the American Section there were over 1500 members in the International Association for Testing Materials, of which about seventy were Americans. There were about twenty present at the organization meeting and thirty at the first annual meeting of the American Section held in Philadelphia almost a quarter of a century ago. In the interim between that meeting and the present annual meeting of this Society lies a remarkable period of achievement in the development of standard methods for testing and of specifications for materials, particularly those used in building construction; in the same period, the membership of the organization has increased nearly forty fold.

The objects of the International Association for Testing Materials were "the development and unification of standard methods of testing for the determination of the properties of the materials of construction and of other materials, and also the perfection of apparatus used for the purpose." The objects of the American Section were "to unite more closely those members living on the western continent and to cooperate in the purposes of the Association."

It early became apparent that with the standardization of the methods of testing, there was a greater need for standard specifications. Very early in the activities of the American Section this was taken up and specifications proposed covering principally metals. In the development of these specifications the great value of the contact between the producer and the consumer was apparent, as was also the need for a broadening of the purposes of the organization.

While the International Association for Testing Materials filled a real need in the engineering world, the value of which was clearly recognized in this country, nevertheless, the experience of its American members which led them to include the formulation of standard specifications as a part of the prime activities of the American Section, did not meet with a sympathetic response from the International Association for the reason that because of national jealousies and keen business competition, it had been found that the formulation of standard specifications was fraught with so many difficulties and so much bitterness that the Association had not attempted to carry on this work, but had confined its activities almost entirely to the field of developing the methods of testing and of the properties of various materials. The American members, however, maintained this broader point of view and believed that the work of developing standard methods and of the properties of materials would be incomplete without the formulation of standard specifications. For four years the American Section endeavored to develop along this broader line but found it difficult to do so as a Section of the International Association and accordingly, on March 21, 1902, the American Section was incorporated as an independent body under the name of the American Society for Testing Materials. While maintaining affiliation as a body with the parent Association, the new Society was free to develop independently in what has become in recent years probably its most important single activity, the formulation of standard specifications for materials. The purpose of the Society, as stated in its charter of incorporation, is "the promotion of the knowledge of the materials of engineering, and the standardization of specifications and the methods of testing."

Standard Specifications for Cement were among the first adopted by the Society and in the formulation of these specifications, the influence of the Philadelphia Municipal Testing Laboratory was largely apparent.

Standard specifications for various materials were adopted at each annual meeting until the volume of standards thus adopted has so increased as to make a very formidable book of upwards of 1100 pages. It is estimated that the Book of Standards that will be published this year will contain 165 standard specifications, recommended practices and methods of tests, and that there will be published 120 tentative specifications and methods. Many of the standards have been published in Spanish and French for the use of the United States Consular Service, in connection with the development of American foreign trade.

The increasing use and the universality of the application of these specifications has had a far-reaching influence upon the quality and upon the economy effected in the manufacture of materials; the influence of the Society has grown until it has a very high reputation and its standards have a world-wide acceptance. The Society forms a unique and invaluable clearing house for the exchange of views of the producer and of the consumer, from which interchange of views the best ideas are crystallized and are reflected in the standards of the Society.

The adoption of standard specifications has proved to be beneficial to the consumer in that it has enabled him to secure a more uniform and higher grade of material at a lower cost than would otherwise be possible. The standard has been evolved as a result of the collective work of the leading experts on the subject and it is common experience that the composite work of many experts is far more valuable than that of a single expert.

The ability to obtain materials of a specified quality has reduced the cost of construction because in the use of the material by reason of the better knowledge of its properties, economies can be effected which would not otherwise be possible. The producer, by reason of uniform standards, can operate his plant uniformly in turning out a standard product, and thereby effect economies in the cost of production.

Probably no consumer of building materials has benefited to a greater extent as the result of the adoption of standard specifications than has the municipality. In the construction of public works there are many influences which render such work difficult, not the least of which is the political influence. The adoption of the standard specifications of this Society eliminates a great deal of undesirable controversies and undesirable competition and results in a greater efficiency in the expenditure of public funds. Where standard specifications are formulated in the manner as are those of this Society, all producers are aware of the fact and can offer less objection to the specifications than would be the case if the specifications, no matter how meritorious, were prepared by the employees of the municipality.

As I review my experience in passing upon materials, I am impressed by the fact that nearly all the controversies that occurred over materials that had to be rejected, related to the methods used in testing the materials. With the establishment of recognized standard methods these controversies have decreased and with the growing respect for the specifications used there has been less attempt to secure the acceptance of inferior materials, and this has resulted in a marked improvement in the work. It would be impossible for a municipality to undertake to carry on the research necessary for the development of specifications as is possible through such an organization as the American Society for Testing Materials. In the first place, the funds available for research are extremely limited and it is the practice of the municipal authorities only to make appropriations for money necessary to cover routine inspection and testing; research work has to be carried on incidentally as funds and the time of the employees permit. The evolution of standards by this method would be extremely slow and even under the most favorable conditions could not be expected to be as efficient as those evolved by this Society where the experience of many experts is reflected in the standards adopted. The multiplicity of materials used in municipal work precludes the possibility of the employment of specialists in all fields, which is so necessary for the development of standards. Through the membership of its employees in this Society and on its committees, the municipality can have the advantage of the experience of the many experts serving on these committees and participating in the general discussions at the annual meetings. The inevitable result of these Society and committee meetings is the broadening and an ever-widening experience of those who attend with a consequent increased service to the municipality. It has been my practice to encourage assistants connected with the work under my charge to become identified with the Society and to participate in its work.

When one considers the important and costly structures that are erected by a municipality, which affect the safety and health of the community, it is readily apparent how important it is that the materials that enter into such structures shall be uniform in quality and of a strength and durability adequate for the service that they are to perform. In the early days of engineering in this country, materials of construction were for the most part passed upon by the engineer by rule-of-thumb methods and later experience has shown how very deceptive such methods are as an indication of quality. For example, it was formerly a practice to test the quality of cement by placing the mortar between two bricks and the quickness with which the bricks would adhere together was an indication of the quality. It was usual years ago in sewer construction to use natural cement in laying the bricks and this quick-setting material showed a rather superior quality in this respect to Portland cement, which set much more slowly. Sand was tested by rubbing it in the hands to see whether it was dirty, and determining whether it was otherwise suitable by visual methods. Those who are experienced in testing know how utterly inefficient and absurd such methods are.

The advantages to the municipality through the adoption of the standards of the American Society for Testing Materials may be briefly stated as follows:

1. Ease in specifying the quality of the material required;

2. Ease in testing materials delivered under the specifications through the use of standard methods;

3. Ease in obtaining standard products;

4. An effective means for minimizing controversies over purchases of materials; and

5. A feeling of security that the materials used are satisfactory, as a result of the knowledge of how the standard specifications are formulated and that they reflect the latest knowledge and experience.

The advantages to the producer may be stated as:

1. Increased efficiency in production through the standardization of the product;

2. The economies effected through this increased efficiency; and

3. Increased output due to the production of standardized materials.

The advantages to the private consumer lie in the fact that by reason of this standardization he obtains materials of greater uniformity, strength and durability, even though he possesses no facilities for making control tests of the materials he purchases.

So many standards have now been adopted and so many committees are beginning to find a decreasing amount of work with the adoption of the specifications they have been engaged in formulating, that it seems it is now desirable to afford an outlet for the activities of such committees along the line recommended in the address of Past-President Capp a year ago, namely, in the development of methods of tests and the properties of materials, and thus perhaps minimize the undesirable tendency to make unnecessary changes in adopted specifications. That is, we should direct more attention to the first of the stated purposes of the organization at the time of its formation, from which we have drifted away.

While the importance of the producer and the consumer meeting on a common ground in the development of standard methods of tests and particularly of standard specifications for material, cannot be over-estimated, nevertheless, it may be well to sound a warning against abuses that may arise in the adoption of standards through the possible dominence of the producer in their formulation. A general belief that this was so would lessen the confidence now felt in these standards. Without any sense of criticism it can be stated that the vital interest of the producer makes it essential that his representative on a committee shall be in attendance at all of its meetings in order that no changes in methods or specifications shall be made which might be detrimental to his interests. Of course, the consumer has a similar interest, but many consumers accept positions on committees as a voluntary matter and attend the meetings of the committees frequently at their own expense. In the case of the municipalities, there are generally no funds available and no way in which the employees may attend such meetings at the expense of the municipality. The representative of the producer is reimbursed for the expense, and the time that is required for this work is part of his duties to the producer. The result is that frequently the producers in attendance at committee meetings are more numerous than the representatives of the consumers. While no one can criticise the producer for showing a keen interest in the development of standards which have a vital bearing on the quality of the materials which he produces, nevertheless, all producers should realize that the American Society for Testing Materials is unique in the almost equal relationship that exists between producers and consumers. Nothing could be more harmful to the Society than to have the predominating attendance of producers at the meetings of committees affect the formulation of standards. This has been the constant concern of the Executive Committee of the Society and every effort has been made to so safeguard its interests as to avoid any possible criticism that may come in this regard. Nevertheless, it is desirable to call attention to the danger in order that this vigilance by the Society may be redoubled, and that the producer may have a keener appreciation of his responsibility. Continued support of the consumers, especially of the representatives of the Federal, State and Municipal Governments, will be dependent entirely on maintaining confidence in the work of the Society, and this confidence can only be maintained by the knowledge that the standards are formulated fairly and that there is not a predominating influence on the part of the producer in the preparation of standards.

I have viewed with great pride the far-reaching influence of the adopted standards, which has resulted in a growing prestige for the Society. Never in its history has there been such intense activity among its committees and the contributions to its annual meetings are limited solely by the amount of funds available for carrying on the work of committees, publishing the annual volume of Proceedings and the triennial Book of Standards, with its supplements. Notwithstanding all this, the work of the Society may be said to have been only fairly started and if the same zealous care is exercised, not only in the formulation of new standards but in the modification of existing standards, the Society will become one of the largest and most influential of the national engineering societies.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE.

The Executive Committee offers the following report of general Society activities for the past year:

Membership.—The continued growth of membership has been very gratifying. The statistics for the past year are shown in the following table:

	1920 Annual Meeting.	1921 Annual Meeting.	Losses.				Additions.		Totals.		
			Transfer.	Resignation.	Dropped.	Death.	Transfer	Election.	Loss.	Gain.	Increase.
Honorary Members	4	4	..	..	..	..	..	..	..	..	..
Members	2,493	2,719	..	86	86	7	63	342	179	405	226
Junior Members	257	185	63	6	30	..	..	27	99	27	72[a]
Totals	2,754	2,908	63	92	116	7	63	369	278	432	154

[a] Decrease.

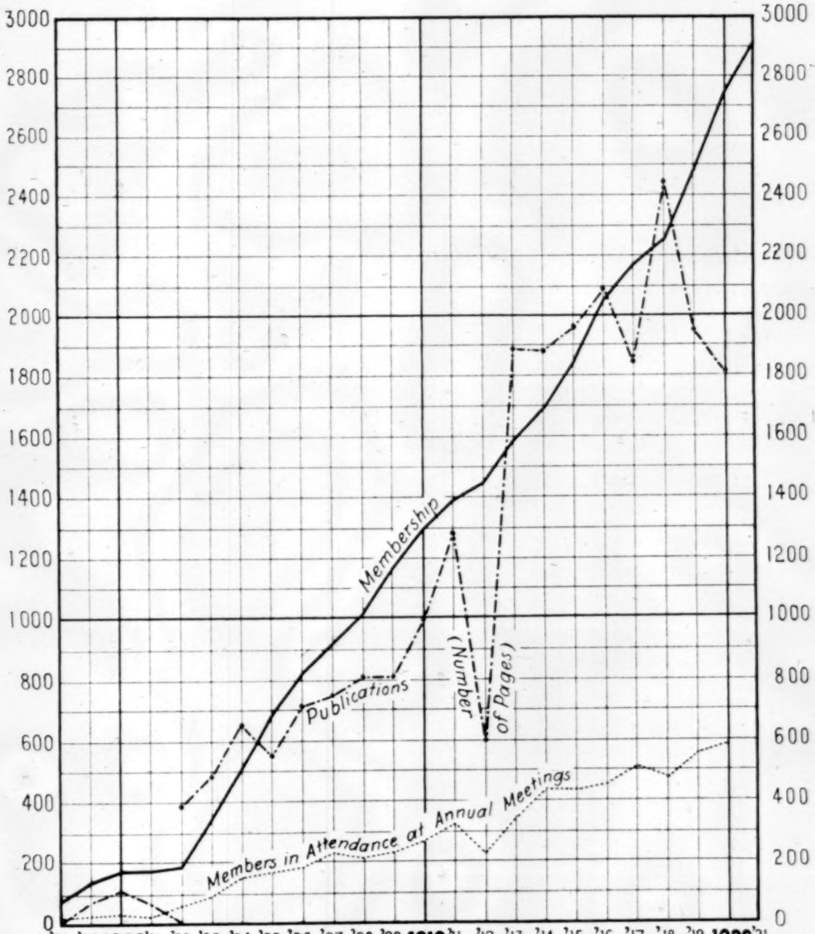
The net increase in membership for the year is 154, whereas for the previous year it was 273. This is undoubtedly to be explained by the period of depression through which we are passing, which is reflected in the greatly increased number of members dropped for non-payment of dues (116, compared with 65 for the preceding year) and the decreased number of new members (369, compared with 440). The number of resignations, 92, is the same as for the previous year. The losses by death number 7, namely: H. L. Haldeman, W. H. Moore, C. J. Osborn, I. B. Thomas, Calvin Tompkins, Guy Wise, Paul L. Wolfel.

The records of the Secretary-Treasurer show clearly the value of the efforts of the individual members of the Society in stimulating the healthy growth of membership. It is estimated that sixty per cent of the new members have been secured either directly or indirectly in this way. Therefore, the Executive Committee tries to keep this important matter before each member of the Society throughout the year by reference to it in the circular letters and Bulletin, accompanied by application blanks for membership which he is asked to place in the hands of persons who would be interested in the work of the Society. Recently, on May 17, the Secretary-Treasurer addressed a personal letter to each member of the Society, sending an application blank and a copy of the program of the annual meeting and requesting that he secure a new member before the meeting if possible. The responses from this letter up to the time of writing this report have been very gratifying, and the efforts of our members exerted in this way will go far towards overcoming the natural difficulties due to the adverse conditions of the present time. The members can also be of help in this direction by recommending individuals or firms to whom the Secretary-Treasurer can send information about the Society's work.

Membership growth since the organization of the Society is shown in the accompanying diagram.

Standing Committees.—Another year of continued activity on the part of the standing committees will be recorded at this meeting. In fact, it is doubtful if there has ever been experienced a more active year in the history of A.S.T.M. committee work. This will be evident from study of the 32 committee reports scheduled for presentation at the meeting, comprising approximately 650 pages, and including recommendations for proposed revisions in 46 standards (of which 8 have been previously reported), adoption of 16 tentative standards as standards, acceptance of 78 proposed new standards as tentative, and proposed revisions in 16 tentative standards to be continued as tentative. In addition, 11 standards are being revised with the recommendation that they be published in the proposed revised form as tentative.

Two new committees have been organized since the last annual meeting: Committee D-14 on Screen Wire Cloth, under the chairmanship of R. W. Woodward, and Committee E-8 on Nomenclature and Definitions, under the chairmanship of Cloyd M. Chapman. The reorganization of Committee E-1 on Methods of Testing, referred to in the annual report a year ago, was effected under the chairmanship of Past-President J. A. Capp. Certain details of organization of the two last-named committees are still under consideration by the Executive Committee. Committee A-4 on Heat Treatment of Iron and Steel has been considerably enlarged. Committee D-2 (formerly on Lubricants) has been enlarged in personnel and scope, the field now assigned to the committee being that of Petroleum Products and Lubricants. Committee D-3 on Methods of Sampling and Analysis of Coal has been discontinued as a separate committee at its own request, and is now the sub-committee on methods of testing of Committee D-5 on Coal. At the request of Committees A-1



NOTE.—The initial curve for publications (1898–1902) refers to the publications of the American Section of the International Association for Testing Materials. The marked drop for 1912 in the "publications" and "members in attendance at annual meetings" curves is due to the fact that the Sixth Congress of the International Association was held in New York in September, 1912, and that the activities of the American Society for that year were accordingly restricted to committee reports and administrative business. The drops of the "publications" curve in 1917 and 1919 are explained by the fact that the Book of A.S.T.M. Standards was not published those years.

on Steel and C-2 on Reinforced Concrete, the Executive Committee has authorized the formation of a special committee on tests of deformed steel concrete reinforcement bars.

The matter of organizing a standing committee on Heavy Chemicals, mentioned in the last annual report, is still under consideration. The Executive Committee is looking into the possibility of organizing committees on Paper and Leather; the latter subject having arisen with special reference to leather belting. Suggestions for organizing committees on Pyrometry and on Temperature Measurements have been referred to Committee E-1 on Methods of Testing for recommendations.

Publications.—The regular publications during 1920 were the Proceedings, the Year Book and the 1920 Supplement to Book of A.S.T.M. Standards. A comparative statement as to the volume of regular publications during the past three years is exhibited in the following:

	1918. Pages.	1919. Pages.	1920. Pages.
Proceedings	1244	1601	1359
Book of A.S.T.M. Standards	908	...	...
Year Book (Membership List)	297	298	320
Supplement to Book of Standards	...	63	128
Totals	2449	1962	1807

In addition, the Society published during 1920 the Book of A.S.T.M. Tentative Standards, which, however, is not classed as a regular publication, since it is simply a collection under separate paper cover of the tentative standards that appear in Part I of the Proceedings and is placed on sale for the convenience of those desiring to have the tentative standards in this form.

Nine circulars to members aggregating 43 pages and one Bulletin of 4 pages have been issued since the last meeting. The Bulletin is a new feature in the publication policy of the Society, and merits a brief reference in this report. With the rapid growth of Society activities, both in our committees and in the development of cooperative work with other organizations, a growing need has been felt for a better means of communication with the members than the present circular letters appearing at irregular intervals, which as a rule have been devoted simply to routine Society business and which are now inadequate as a medium for properly informing the members and others about current Society affairs. Although the committee reports and papers are presented to the Society only at the annual meetings, we are continually at work. Many developments during the year in our committee work and in joint activities with other societies are of immediate interest to the members and to industry in general, and constitute "news" about our work that should be disseminated promptly. The Executive Committee, upon the recommendation of Committee E-6 on Papers and Publications, therefore decided to expand the facilities for publishing such information by issuing a Bulletin at approximately quarterly intervals, which will replace four of the circular letters. The remaining circulars, which will relate principally to details of the annual meeting and to nomination and election of officers, will be published as usual. In this way the members will be kept in closer touch with every-day happenings in the Society and its committees, which will be of advantage both to the members individually and to the Society as a whole. The Bulletin will also be sent to the secretaries of a number of societies and to a selected number of technical and trade journals in this country and abroad. The Bulletin is particularly designed to afford the committees an opportunity to secure greater publicity of their work as it develops between annual meetings, and as much space as possible will be devoted to items of interest about committee activities. It is not intended to publish committee reports or technical papers in the Bulletin.

The first number of the Bulletin was published April 1, 1921, and so far as the Executive Committee has been able to learn it has been very favorably received by the members and others. The estimated *increased* expense this year of publishing the Bulletin is about $400, which the Executive Committee believes is entirely justified by the advantages to be gained, notwithstanding the difficult printing situation referred to later.

This year the second edition of the Book of A.S.T.M. Standards under the plan of triennial publication will be published. The 1918 edition, with the two supplements issued in 1919 and 1920, comprised 159 standard specifications, methods, definitions and recommended practice. The 1921 edition will contain these standards in their revised form as determined by action of the annual meeting, and such of the present tentative standards as may be adopted as standard at the meeting. It is estimated that the volume will contain about 1000 pages, and it naturally will be the largest and most valuable compilation of the Society's standards yet published.

The anticipated publication of this volume at a cost of nearly 100 per cent above the printing costs of 1918, has made the 1921 publication program a difficult one. At the beginning of the year, the entire situation was carefully studied by the Finance Committee and Committee E-6 on Papers and Publications in connection with the preparation of the budget, in order to determine upon a program that would keep publication expenditures, based upon estimated unit costs, within estimated receipts for this year. Permanent measures of economy have been effected by changing the size of type page from 4 by 6½ in. to 4⅓ by 7 in., and by making certain changes in arrangement of standards, which, together, will effect a saving this year of perhaps 8 per cent in the number of printed pages in the Proceedings and Book of Standards. The savings effected by these measures, while considerable, are not nearly sufficient to meet the emergency created this year. Recognizing that in the case of a triennial publication such as the Book of Standards the expense should be distributed over three years, the Executive Committee set aside $2000 from the receipts of 1919 and a like sum in 1920, as a sinking fund towards defraying expenses of the 1921 edition. These sums, however, are quite inadequate in view of present printing costs. Accordingly, the Committee on Papers and Publications has been directed to effect every possible economy in the publication of the Proceedings. The saving in space effected by the increased size of type page, together with efforts made to reduce the average length of the technical papers for this year, is expected to make it possible to bind the 1921 Proceedings in one volume, at a considerable saving in cost. It will also be necessary for this year—unless printing costs are greatly reduced within the next few months—to omit the publication of the Year Book, issuing to each member in its place a supplement to the 1920 edition containing list of officers, list of new members since the 1920 edition was published, and other supplementary information of importance. The savings thus effected will enable the Society to meet the obligation to publish its reports, papers and standards without exceeding the receipts for the year, which the Executive Committee conceives to be the sound policy upon which it should proceed.

An Index of Proceedings from Vols. I to XII, inclusive (1898–1912), was published in 1912. The "copy" for an index of Vols. XIII to XX, inclusive, covering the years 1913 to 1920, is being prepared, but publication will have to be deferred until conditions are more favorable.

Headquarters.—The Society is now well established in its headquarters in the Engineers' Club Building, which were first occupied a year and a half ago. The offices are admirably adapted to the Society's work. In particular, excellent facilities are now available at Society headquarters for committee meetings and have been much used by the committees. The following table will be of interest:

Number of Meetings.

	Committees.	Sub-Committees.	Committees of Other Societies.	Total.
During 1920	30	56	4	90
January-May, 1921	21	22	3	46
Total	51	78	7	136

The Executive Committee requests that committees and members of the Society continue to make use of Society headquarters in every way possible.

Finances.—The annual statement of the finances of the Society follows in the form of the report of the auditors for the fiscal year January 1, 1920, to December 31, 1920.

When establishing its headquarters in the fall of 1919 the Society entered into an agreement with the Engineers' Club of Philadelphia by which it was to pay the cost of necessary alterations to the Club building, this sum to be accepted by the Club as advance payment of rent at the rate of $1000 a year. This agreement became effective on January 1, 1920, and the total amount paid by the Society was $4467.17.

The loan of $2200 referred to in the report was a temporary thirty-day loan created in order to pay all bills for 1920 in that year. It was thought best to do this, in order to make a cash statement comparable with those of former years rather than to hold the bills over for payment out of the dues for this year or to dispose of investments.

The surplus on December 31, 1920, was $24,986.02 and includes the $1300 Life Membership Fund, $3467.17 for rent paid in advance, $2430.31 for furniture and fixtures, and $4000 invested in a sinking fund towards defraying the cost of the 1921 Book of Standards.

Receipts from Sales of Publications.—The receipts from the sales of publications have increased each year for many years, and for 1920 reached the sum of $10,983.37, which is nearly $1700 greater than for the preceding year. These receipts form an important source of income of the Society, the figure for 1920 representing about 22 per cent of the total receipts for the year. Since it is obviously of advantage to all concerned that the Society's publications should be as widely disseminated as possible, the Executive Committee has endeavored to stimulate the sale of publications in a dignified way befitting the Society's standing as a national technical society. The appearance of the 1920 Proceedings was advertised in two of the leading technical journals for four issues each. Nine hundred public, technical and industrial libraries not members of the Society, including

REPORT OF AUDITORS FOR THE FISCAL YEAR JANUARY 1, 1920, TO DECEMBER 31, 1920.

JOHN HEINS AND CO.
PUBLIC ACCOUNTANTS AND AUDITORS

PHILADELPHIA, January 5, 1921.

AMERICAN SOCIETY FOR TESTING MATERIALS,
MR. C. L. WARWICK, *Secretary-Treasurer*,
Philadelphia, Pa.

Dear Sirs:

We respectfully report that we have made an audit and examination of the books and accounts of your Society for the six months ended December 31, 1920, having previously made a similar audit and report for the preceding six months ended June 30, 1920, and at both audits found the accounts to be correct and to be in their usual excellent condition.

We submit balance sheet as of December 31, 1920, as also a statement of cash receipts and disbursements for the twelve months then ended.

We have verified the transactions set forth in the budget record for the last six months as also for the six months ended June 30, last, as reported in ours of July 20th and found the same to be correct.

Respectfully submitted,
(Signed) JOHN HEINS AND CO.

BALANCE SHEET AS OF DECEMBER 31, 1920.

ASSETS.

Cash		$265.05
Investments:		
$17,200 U. S. Liberty Loan Bonds[1] 4th 4¼'s	$16,380.64	
1,300 U. S. Liberty Loan Bonds, 4th 4¼'s, held for Life Membership Fund	1,227.45	
		17,608.09
Accounts Receivable:		
For Publications	$1,797.70	
Members for 1920 dues	1,956.20	
Members for binding	70.00	
		3,823.90
Rent paid in advance		3,467.17
Furniture and fixtures		2,430.31
		$27,594.52

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[1] $3000 of the above U. S. Liberty bonds are deposited with the Girard Trust Co. as collateral on a loan of $2200.

LIABILITIES.

Accounts Payable (loan)		$2,200.00	
Members dues paid in advance	$405.50		
Members binding paid in advance	3.00		
		408.50	
Life Membership	$1,300.00		
Surplus	23,686.02		
		24,986.02	
			$27,594.52

NOTE.—The stock of back publications is not appraised or included in this statement.

MISCELLANEOUS FUNDS.

In addition to the above cash the Secretary-Treasurer has on hand the following funds:

Committee A-5 on Corrosion of Iron and Steel	$1,414.77	
Committee C-1 on Cement	2,053.55	
Committee C-9 on Concrete and Concrete Aggregates	617.73	
Committee C-10 on Hollow Building Tile	190.33	
Joint Committee on Investigation of Phosphorus and Sulfur in Steel	175.17	
		$4,451.55

RECEIPTS AND DISBURSEMENTS.
JANUARY 1, 1920, TO DECEMBER 31, 1920.

Cash on hand, January 1, 1920			$294.70

RECEIPTS.

Current dues	$39,059.47		
Past dues	532.50		
Advance dues	405.50		
		$39,997.47	
Sale of Publications:			
Separate Standards	$1,950.85		
Book of Standards	2,996.62		
Book of Tentative Standards	603.53		
Proceedings	3,137.57		
Miscellaneous	2,294.80		
		10,983.37	
Binding (Members)		957.00	
Sale of right to reprint Standards		1,025.00	
Authors' reprints		421.67	
Sale of Certificates of Membership		44.50	
Interest on deposits and investments		1,537.26	
Accrued interest		102.71	
Girard Trust Co., loan		2,200.00	
Excess remittances		97.68	
Miscellaneous		116.52	
Total receipts			57,483.18
			$57,777.88

Brought forward		$57,777.88

DISBURSEMENTS.

Publications	$30,522.08	
Salaries	13,174.90	
Expenses, Secretary-Treasurer's Office	2,949.46	
Expenses, Standing Committees	1,505.59	
Expenses, Nominating Committee	134.23	
Traveling Expenses, Executive Committee	768.33	
Rent and insurance, storage rooms	291.60	
Engrossing Certificates of Membership	87.50	
American Engineering Standards Committee	1,500.00	
Engineering Council	1,000.00	
Expenses, Representative on Engineering Council	37.68	
Joint Committee on Specifications for Reinforced Concrete	100.00	
Joint Committee on Investigation of Phosphorus and Sulfur in Steel	25.00	
Advance rent, new headquarters	867.17	
Furniture and Fixtures	2,029.91	
Expenses incidental to establishing headquarters	312.48	
Investments	2,006.51	
Accrued interest	102.71	
Refund of excess remittances	97.68	
Total disbursements		57,512.83
Cash on hand December 31, 1920		$265.05

FINANCIAL CONDITION AT CLOSE OF FISCAL YEARS 1916–1920, INCLUSIVE.

Fiscal Year.	Assets.					Liabilities.	Surplus.
	Cash Balance.	Investment Liberty Bonds.	Accounts Receivable	Advance Rent and Furniture and Fixtures.	Total.	Accounts Payable.[a]	Surplus.[b]
1916	$845.78	....	$2 595.24	....	$3 441.02	$300.93	$3 140.09
1917	9 584.82	....	2 601.71	....	12 186.53	231.00	11 955.53
1918	7 164.93	$4 880.63	2 569.95	....	14 615.51	331.47	14 284.04
1919	294.70	15 601.58	3 415.40	$3 600.00	22 911.68	417.25	22 494.43
1920	265.05	17 608.09	3 823.90	5 897.48	27 594.52	2 608.50	24 986.02

[a] These sums represent dues paid in advance and do not include any unpaid bills except, for 1920, a loan of $2200 from the Girard Trust Company.

[b] These items include $1300 on account of Life Memberships.

a few in foreign countries, were circularized recently in an endeavor to dispose of complete sets of Proceedings and of interesting the libraries in membership. The results to date have been rather gratifying.

It is believed the wide distribution of the A.S.T.M. Bulletin will be very helpful in bringing the Society's publications prominently to the attention of persons to whom they would be of interest and value.

Inventory of Publications in Stock.—In the foregoing financial analysis no account has been taken of the assets of the Society in the form of publications in stock. The inventory on May 14, 1921, may be summarized as follows:

	Number of Copies
Proceedings	7,573
1918 Book of A.S.T.M. Standards	517
Index (Vols I–XII, incl.)	634
Reports of Committee D-1 (1903–1914 incl.)	327
1920 Book of A.S.T.M. Tentative Standards	85

Increased Use of Society's Standards.—The use of the Society's specifications and methods of test for materials is undoubtedly becoming more and more extended. This is made evident principally in two ways: First, by the increase in sales of the standards both in collective form through the Book of A.S.T.M. Standards and in the form of separate copies; and second, the increased use by engineers and architects in their specifications, particularly so in the case of municipal, state and federal governments, and public service bodies. There has been a marked increase during the past year in the number of requests for information about the Society's standards and their applicability to various problems of construction.

Within recent years the use of the Society's specifications in export trade has been steadily increasing. It was largely with the thought in view of aiding export trade that the Society entered into an agreement with the U. S. Department of Commerce in 1916 by which those of its standard specifications which have an important bearing on the requirements of export trade were to be translated into foreign languages and distributed in the form of bi-lingual editions among the various United States consular offices. The printing of Spanish-English editions of some 62 specifications and their distribution in this way was completed in 1919. Since that time the same specifications have been translated into French, and French-English editions are now in press. Plans for the wide distribution of these specifications are being considered by the Executive Committee in consultation with the Department of Commerce.

It has seemed desirable to the Executive Committee that steps should be taken to see that the standards of the Society become better known in foreign countries, and particularly that they may be available for consultation in connection with export orders. Accordingly complimentary copies of the Society's standards have been sent to all of our commercial attaches in foreign countries and to the foreign embassies and legations at Washington, with an appropriate letter calling attention to the Society's activities and to the importance that its standards have assumed in this country.

Specifying of Patented Apparatus in Standards.—The Tag Closed Tester, specified as the instrument for flash point test in the Society's present Standard Tests for Flash Point of Volatile Paint Thinners (D 56 – 19), was developed by Committee D-1 on Preservative Coatings for Structural Materials in coöperation with the C. J. Tagliabue Manufacturing Co. This instrument was devised as the result of an exhaustive study by the committee, begun in 1914, of the principal instruments for determining flash point then on the market.[1]

A patent on the instrument was granted to Charles J. Tagliabue and is now owned by the Tagliabue Co. Through an oversight on the part of Committee D-1, which has been explained with entire satisfaction to the Executive Committee, the instrument was adopted as standard by the Society without prior consideration by the Executive Committee, as required by the By-laws in the case of the use in the Society's standards of any devices which form the subject matter of an existing patent. The situation has been carefully reviewed by the Executive Committee, in consultation with Committee D-1 and the Tagliabue Co., and it has been decided to execute an agreement with the Tagliabue Co. by which that company will issue licenses for the nominal sum of One Dollar ($1.00) to other manufacturers, approved by the Executive Committee of the Society, permitting them to make the Tag Closed Tester, all Testers so made to bear a name plate with the following inscription:

TAG CLOSED FLASH POINT TESTER
A.S.T.M. STANDARD
LICENSED UNDER TAGLIABUE PATENT NO. 67583.

In addition, the name of the manufacturer who obtains the license and manufactures the Tester thereunder is to appear on the Tester.

This agreement is now being drawn up and will be formally executed in due course.

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[1] Complete reports of these tests are included in the reports of Committee D-1. *Proceedings*, Am. Soc. Test. Mats., Vols. XIV to XVIII, inclusive, Part I (1914–1918).

Promotion of Knowledge of Engineering Materials.—The members of the Society will recall the suggestion in the Presidential Address a year ago of Past-President J. A. Capp which, expressed briefly, is that the Society should consider the desirability of stimulating and consciously directing activities that will promote the knowledge of materials on a broad and comprehensive scale, and give to this side of our work the same careful study that has been given to the other of the two broad objects for which the Society was organized, namely, the standardization of specifications and methods of testing. This suggestion so impressed the Executive Committee that the subject has been referred to a special committee for study and report. The Executive Committee is not prepared to make definite recommendations at this time nor to outline a proposed policy. A brief résumé of the matter, however, based upon the study that has so far been given it, will throw some light on its importance. The problem divides itself broadly into two parts: (1) The study of the properties upon which depends the suitability of a material for particular applications and the use of these properties to measure suitability; and (2) more intensive study of methods of test of materials: not only tests which are used as "control tests" to insure delivery of material of certain specified requirements, but particularly with regard to what might be called "suitability tests" designed to determine the inherent qualities of materials upon which their suitability for a given service depends. The reorganization of Committee E-1 on Methods of Testing, announced last year, furnishes an opportune means of stimulating study of the second problem among the committees of the Society. This phase of the matter has therefore been referred to Committee E-1 for development.

The broader problem of stimulating the study of properties of materials will require careful consideration in order that it may be developed in the best way. The problem is essentially one of research and investigation, which does not necessarily stop at the issuance of specifications in so far as the latter may be the principal activity of any committee. The Executive Committee accordingly intends to address itself to the question "How can research and investigation of engineering materials be stimulated in the Society?" Methods of stimulating research among the Society members and the possibility of developing for the work of promoting knowledge of materials the same type of organization that has proved so efficient in the Society's standardization work, are being considered and will be reported upon later.

Materials Engineering Education.—During the year the Executive Committee has considered the desirability of the Society devoting some attention, as a Society, to the problem of engineering education, particularly with respect to the study of materials in the engineering and technical colleges of the country. This is an important matter, for there is to-day a very evident trend towards the development of a distinct class of "materials engineers." Moreover, such work would seem to be entirely consistent with one of the objects for which the Society is organized, that is, the promotion of knowledge of engineering materials. After careful consideration it has been decided to appoint a standing committee on Materials Engineering Education, which is to include not only men engaged in the profession of engineering education who are able to devote the necessary time to committee work, but also men who are practicing engineers or who represent firms utilizing the services of men specializing in materials engineering, in order that their practical knowledge of the development of this specialty can be contributed to the study of the problem. It is fully realized that the task is a large one, which will require careful and painstaking study. The Executive Committee feels, however, that the Society by undertaking this work in a thorough manner can render an important service and that the problem is one deserving of the most careful consideration both by members individually and by the Society as a body.

Federated American Engineering Societies.—At the last annual meeting the Executive Committee reported the decision of a conference of representatives of national, local, state and regional engineering and allied technical organizations to recommend to these organizations the formation of a body to be known as the Federated American Engineering Societies; and at one of the sessions of that meeting the Executive Committee explained that it had been in close, sympathetic touch with this movement and had continued its delegates to the organizing conference as a special committee on the subject. Since the meeting the formal organization of the Federation was completed in November, 1920, at a meeting held in Washington, at which the Society was represented. The Society duly received a formal invitation to become a Charter Member of the Federation. In acknowledging this invitation the Executive Committee replied that the questions involved in its consideration were such that it was felt they should be decided by the membership of the Society itself at the next annual meeting.

In order that the members might be as fully informed as possible concerning the organization and objects of the Federation there was sent on December 3, 1920, on behalf of the Executive Committee, to each member of the Society a circular letter giving pertinent information about the Federation and its contemplated activities, with which was transmitted a printed copy of the Constitution and By-laws of the Federation. The Executive Committee also solicited communications from the members giving an expression of their views concerning the Federation and the invitation that the Society should become a Charter Member.

In the meantime the former Engineering Council, upon which the Society was represented by Vice-President C. D. Young, was formally dissolved as of December 31, 1920, and its activities in general were turned over for development by the Federated American Engineering Societies.

Believing that the membership of the Society looks to the Executive Committee to recommend what it conceives to be the proper course of action in this matter, the Executive Committee has kept in touch with the activities of the Federation and has been represented informally by invitation at the meetings of its Executive Board. At the next quarterly meeting of the Executive Committee, to be held during the annual meeting on June 22, this matter will receive final consideration in the form of a report of its special committee, and the report of the Executive Committee to the annual meeting will be presented at the session on Thursday morning, June 23.

American Engineering Standards Committee.—The Society has continued to take an active part in the work of the American Engineering Standards Committee. Following its reorganization, as announced in the last annual report of the Executive Committee, the Standards Committee has been quite active in promoting general standardization projects. The Executive Committee has kept the Society members informed of the progress in the work of the Standards Committee, in so far as it is of immediate interest to the Society, through the circular letters and more recently the first issue of the A.S.T.M. Bulletin. Accordingly the Executive Committee will in this report refer briefly only to several matters of particular interest.

Five standards of the Society have been offered to the Standards Committee and approved by them as Tentative American Standards, as follows:

Standard Specifications and Tests for Portland Cement, in their latest revised form (C 9 - 21);

Standard Specifications for Fire Tests of Materials and Construction (C 19 - 18);

Standard Test for Toughness of Rock (D 3 - 18);

Standard Method for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 18);

Standard Methods for Sampling of Coal (D 21 - 16).

The following four standards have been offered to the Standards Committee and action concerning their adoption as Tentative American Standards is pending:

Standard Specifications for Soft or Annealed Copper Wire (B 3 - 15);

Standard Specifications for Lake Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (B 4 - 13);

Standard Specifications for Electrolytic Copper Wire Bars, Cakes, Slabs, Billets, Ingots and Ingot Bars (B 5 - 13);

Standard Methods for Battery Assay of Copper (B 34 - 20).

The Standard Specifications for Drain Tile (C 4 - 16) and the Standard Test for Penetration of Bituminous Materials (D 5 - 16), which were mentioned in the last annual report as having been submitted to the Standards Committee, were withdrawn during the year on account of revisions proposed by the committees of the Society responsible for them. If these revisions are approved at the approaching annual meeting, the standards will again be offered for approval by the Standards Committee.

Other standards, including a number of the specifications for steel, are under consideration by the Executive Committee for submission in the near future.

In cooperation with the American Zinc Institute, the Society has organized a committee on Zinc and Zinc Ores which will function as a sectional committee of the Standards Committee under its Rules of Procedure. One of the primary objects in forming the committee is to furnish a means whereby this country can be represented in the international standardization of zinc and zinc ores that has been proposed by the Belgian Standardization Association. The work of this committee will be closely coordinated with that of Committee B-2 on Non-Ferrous Metals and Alloys, particularly in so far as specifications and methods of analysis are concerned.

The Standards Committee is at present undertaking the development of standardization of insulated wire and cables for other than telephone and telegraph use. Uniform national standards in this field are of much importance, particularly in connection with export trade. Conferences have been held at which the leading national organizations interested in the problem have been represented and it is expected to organize in the near future a representative sectional committee that will undertake the unification of existing specifications for insulated wire and cable and the development of new standards where necessary. The Society has already done considerable work in the preparation of specifications for bare copper wire and cables and for rubber insulated wire and cable and will take an active part in the further development of this program.

Division of Engineering of the National Research Council.—Since the last annual meeting, Past-President J. A. Capp and Vice-President G. K. Burgess have been appointed to represent the Society on the Division of Engineering of the National Research Council, succeeding Past-President A. A. Stevenson, who resigned to become a "member at large" of the Division.

The Society is cooperating with the Division of Engineering in several research projects, including high-speed tool steel, heat treatment of steel, and magnetic analysis. The Division is also represented on the Joint Committee on Investigation of Phosphorus and Sulfur in Steel.

During the year the Division of Engineering, with the support of the U. S. Bureau of Public Roads, has undertaken to develop a national highway research program, in view of the urgent need for a systematic program which will place road building on a sound engineering basis and make it possible to expend economically the large sums of money appropriated for roads. An Advisory Board on Highway Research has been formed, upon which the Society has designated Prevost Hubbard as its representative, with A. N. Johnson as alternate. The primary object of this movement is to coordinate the several agencies that are now at work on various aspects of highway development, which include economic theory, structural design, and character and use of materials. The work of a committee of the Division of Engineering on the last-named subject has been effectively coordinated with the activities of Committee D-4 on Road and Paving materials.

The American Bureau of Welding, which was formed some time ago as a research bureau of the American Welding Society, has during the past year become a joint advisory board of that Society and the Division of Engineering on welding research and standardization. The Society has continued its representation on this Bureau through F. M. Farmer. A comprehensive program covering this field has been announced, in which the Society will be able to be of some assistance, especially in the consideration of specifications for steel to be welded. The Executive Committee has asked Committee A-1 on Steel to appoint representatives on the committee of the American Bureau of Welding that will study this subject.

During the year there was held under the auspices of the Division of Engineering a conference on insulation research at which the Society was duly represented by invitation. While it is intended to undertake research of insulation problems along fundamental lines, the details are yet to be worked out.

Cooperation with A.S.M.E. Boiler Code Committee.—The Society has continued its cooperation with the American Society of Mechanical Engineers in the matter of specifications for materials that are included in the Boiler Code of that Society. Formal conferences of the duly authorized representatives of the two societies have been held during the past year to discuss such matters as specifications for boiler plate, uniform specifications for boiler tubes covering locomotive, stationary and marine practice, and specifications for welded steel pipe, in all of which representation of the standing committees of the Society has been had. In particular the annual report of Committee A-1 on Steel will contain reference to these matters. In addition, the attention of the Boiler Code Committee has been called to changes that have been made or are being recommended for consideration at the approaching annual meeting in a number of A.S.T.M. specifications since they were incorporated or referred to in the Boiler Code. It has been the desire on the part of both societies that the next revision of the Boiler Code will be as nearly as possible in accord, in so far as specifications for materials are concerned, with the corresponding requirements of the Society as they will be determined by action at the annual meeting, and the cooperative work will therefore be continued with this end in view.

Miscellaneous Joint Committees.—The Society has continued during the past year its participation in the work of the several joint committees upon which it has appointed representatives, as follows:

The Joint Committee on Investigation of Phosphorus and Sulfur in Steel has made good progress in its work, which so far has been confined to the effect of sulfur in certain grades of steel. It is expected that some of the tests that have been made within the past year will be formally reported upon by the committee in the near future.

The Joint Committee on Standard Specifications for Concrete and Reinforced Concrete has been actively at work since its formal organization in February, 1920, and has presented its first report, comprising Tentative Specifications for Concrete and Reinforced Concrete, to the governing boards of the five societies represented on the committee. Although the report in its final corrected form was not received until early in June, every effort will be made to have it ready in preprint form for distribution at the annual meeting.

The Joint Committee on Concrete Culvert Pipe has continued its work. During the year it requested the Society to prepare specifications for cold-drawn wire for reinforcing. This request was referred to Committee A-1 on Steel and that committee is submitting this year to the Society Proposed Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement.

The Joint Committee on Standard Pattern Practice has been somewhat delayed in starting the work for which it is organized; but during the past year the American Foundrymen's Association, which has assumed sponsorship for the project, has made good progress in getting the work under way.

Other Cooperative Work.—The Society is working in cooperation with the Government and the American Petroleum Institute in the development of methods of test and specifications for petroleum products. This is being done through Committee D-2 on Petroleum Products and Lubricants upon which both of these bodies are represented. In addition, the Society has appointed T. G. Delbridge as its representative on an advisory board which has been organized by the U. S. Departmental Committee on Standardization of Petroleum Specifications to enable the Government to keep in close touch with the activities of the various national organizations that are at work in this field. P. H. Conradson is also serving as a representative of the Society on a committee of the American Petroleum Institute on improvement in methods.

Cooperation with the Society of Automotive Engineers, the American Society for Steel Treating, and the Division of Engineering of the National Research Council in the study of matters relating to heat treatment of iron and steel has been arranged through Committee A-4 on Heat Treatment of Iron and Steel.

During the year the Society has, upon invitation, become affiliated with the American Association for the Advancement of Science and will be represented on its Council by the Secretary-Treasurer.

The Society has also accepted membership on the U. S. National Committee of the International Electrotechnical Commission.

Respectfully submitted on behalf of the Executive Committee,

GEORGE S. WEBSTER,
President.

C. L. WARWICK,
Secretary-Treasurer.

REPORT OF COMMITTEE A-1
ON
STEEL.

During the past year Committee A-1 has held two meetings, one on October 1, 1920, and the second on March 4, 1921. A third meeting will be held prior to the presentation of this report to the Society, at which the report will be finally reviewed and other matters considered.

The Advisory Committee has held two meetings, at which matters concerning the general administrative affairs of the committee were considered.

The present membership of the committee is 125, of which 72 are classified as non-producers and 53 as producers.

Sub-Committees.—Two new sub-committees have been appointed during the year: Sub-Committee XIII on Methods of Testing and Sub-Committee XVIII on Nomenclature and Definitions. The committee has also approved the appointment of a third new sub-committee, XIX on Steel Sheets. The function of this sub-committee is to be the preparation of specifications for steel sheets of any and all grades for which there may appear to be a demand. No action has yet been taken towards appointing the chairman and members of this sub-committee.

As announced at the last annual meeting, the committee has also appointed representatives on Committee E-1 on Methods of Testing and on Committee E-8 on Nomenclature and Definitions.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS.

The recommendations of the committee affecting standards and tentative standards are presented first in summarized form together with an analysis of the letter ballot on each item. They are then referred to where necessary in greater detail, being grouped for convenience in the order of the respective sub-committees directly responsible for them.

I. Proposed Revisions in Standards.—The committee recommends that the revisions in the following standards, Nos. 1 to 35, inclusive, in the Appendix to this report, be referred to letter ballot of the Society for adoption as standard. The revisions are divided into two groups:

A.—Revisions proposed at the 1919 and 1920 annual meetings and now recommended for adoption by letter ballot.

B.—Revisions now proposed for the first time, which the committee recommends be referred to letter ballot of the Society by the necessary nine-tenths vote of the annual meeting.

The standard specifications in each group are as follows:

GROUP A.

(*a*) *Revisions Recommended for Adoption as presented in 1919,*[1] *without Amendment:*

For Open-hearth Steel Girder and High Tee Rails (A 2 – 12).

(*b*) *Revisions Recommended for Adoption as presented in 1920,*[2] *without Amendment:*

For Quenched Carbon-Steel Track Bolts (A 50 – 16).
For Quenched Alloy-Steel Track Bolts (A 51 – 16).
For Steel Screw Spikes (A 66 – 18).
For Structural Steel for Bridges (A 7 – 16).
For Structural Nickel Steel (A 8 – 16).
For Structural Steel for Buildings (A 9 – 16).
For Structural Steel for Locomotives (A 10 – 16).
For Structural Steel for Cars (A 11 – 16).
For Rivet Steel for Ships (A 13 – 14).
For Boiler Rivet Steel (A 31 – 14).
For Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 18).

(*c*) *Revisions Recommended for Adoption as presented in 1920*[2] *and Amended in 1921 as indicated in the Appendix.*

For Quenched High-Carbon-Steel Splice Bars (A 49 – 15).
For Welded Steel Pipe (A 53 – 18). A revision in the form of new specifications was presented a year ago. They have since been revised and are appended in amended form for adoption as standard.[3]
For Automobile Carbon and Alloy Steels (A 29 – 18).

GROUP B.

Revisions Proposed for First Time, and Recommended for Adoption:

Items Nos. 1 to 34 in the Appendix and in the table on analysis of votes.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XIX, Part I, p. 777 (1919).

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, pp. 809 ff. (1920).

[3] See 1921 Book of A.S.T.M. Standards.—ED.

II. Proposed Revisions in Tentative Standards Continued as Tentative.—The committee recommends that the revisions in the following tentative specifications which appear in the Appendix to this report, be approved:

For Tie Plates (A 67 - 18 T).
For Low-Carbon-Steel Track Plates (A 76 - 18 T).
For Steel Plates for Forge Welding (A 78 - 20 T).
For Boiler and Firebox Steel for Stationary Service (A 70 - 18 T).
For Carbon Tool Steel (A 71 - 20 T).

III. Proposed New Tentative Standards.—The committee recommends that the following two new tentative specifications, which are appended to this report,[1] be accepted for publication as tentative:

For Cold-Drawn Steel Wire for Concrete Reinforcement.
For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes.

IV. Tentative Specifications to be Advanced to Standard.—The committee recommends that the following tentative specifications be submitted to letter ballot of the Socity for adoption as standard:

For Commercial Bar Steels (A 80 - 20 T).

The above recommendations have been referred to letter ballot vote of the committee, which consists of 125 members; 115 ballots have been cast, 10 members have refrained from voting. The analysis of the vote of the committee is given in Table I.

In the following the committee presents the foregoing recommendations in detail where necessary, as well as other features of its work, grouped for convenience in the order of the respective subcommittees responsible for them.

PHOSPHORUS AND SULFUR NOTE IN A.S.T.M. SPECIFICATIONS.

The committee has given careful consideration to the note concerning phosphorus and sulfur which by action at the last convention was allowed to remain on fourteen specifications, and has recommended that this note be removed from all specifications and that the sulfur requirement be raised 0.01 per cent in four specifications, and the phosphorus requirement for acid steel be raised 0.01 per cent in one specification.

In explanation of these recommendations we would point out that of the fourteen specifications which now carry the note, the note affects the phosphorus in Bessemer steel in the Specifications for

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[1] See pp. 459-467.—ED.

TABLE I.—ANALYSIS OF VOTE ON REPORT OF COMMITTEE A-1.

Items.	Affirmative.	Negative.	Not Voting.[a]
I. PROPOSED REVISIONS IN STANDARDS.			
1. For Carbon-Steel Rails (A 1-14)	56	3	56
2. For Quenched High-Carbon-Steel Splice Bars (A 49 – 15)	60	0	55
3. For Quenched Carbon-Steel Track Bolts (A 50 – 16)	65	2	48
4. For Steel Track Spikes (A 65 – 18)	62	1	52
5. For Steel Screw Spikes (A 66 – 18)	60	1	54
6. For Low-Carbon-Steel Splice Bars (A 3 – 14)	63	2	52
7. For Quenched Alloy-Steel Track Bolts (A 51 – 16)	63	3	49
8. For Structural Steel for Bridges (A 7 – 16)	70	2	43
9. For Structural Nickel Steel (A 8 – 16)	69	2	44
10. For Structural Steel for Buildings (A 9 – 16)	69	2	44
11. For Structural Steel for Locomotives (A 10 – 16)	69	1	45
12. For Structural Steel for Cars (A 11 – 16)	71	1	43
13. For Carbon-Steel Bars for Railway Springs (A 14 – 16)	80	0	35
14. For Carbon-Steel Bars for Railway Springs with Special Silicon Requirement (A 68 – 18)	75	0	40
15. For Carbon-Steel Bars for Vehicle and Automobile Springs (A 58 – 16)	72	0	43
16. For Silico-Manganese-Steel Bars for Automobile and Railway Springs (A 59 – 16)	73	0	42
17. For Chrome-Vanadium-Steel Bars for Automobile and Railway Springs (A 60 – 16)	72	0	43
18. For Billet Steel Concrete Reinforcement Bars (A 15 – 14)	71	0	44
19. For Carbon-Steel and Alloy-Steel Blooms, Billets and Slabs for Forgings (A 17 – 18)	84	2	29
20. For Carbon-Steel and Alloy-Steel Forgings (A 18 – 18)	86	0	29
21. For Quenched-and-Tempered Carbon-Steel Axles, Shafts, etc., for Locomotives and Cars (A 19 – 18)	76	3	36
22. For Quenched-and-Tempered Alloy-Steel Axles, Shafts, etc., for Locomotives and Cars (A 63 – 18)	73	3	39
23. For Carbon-Steel Forgings for Locomotives (A 20 – 16)	74	1	40
24. For Cold-Rolled Steel Axles (A 22 – 16)	69	1	45
25. For Steel Castings (A 27 – 16)	80	6	29
26. For Lap-Welded and Seamless Steel Boiler Tubes for Locomotives (A 28 – 18)	65	3	47
27. For Automobile Carbon and Alloy Steels (A 29 – 18)	71	0	44
28. For Boiler and Firebox Steel for Locomotives (A 30 –18)	67	0	48
Phosphorus and Sulfur Allowances:			
29. To remove Note on Phosphorus and Sulfur Allowances from the fourteen specifications affected (See 1920 Report of Committee A-1 to Society)[1]	94	5	16
To increase the maximum sulfur allowance 0.01 per cent in specifications:			30
30. For Structural Steel for Locomotives (A 10 – 16)	73	12	30
31. For Structural Steel for Cars (Structural grade only) (A 11 – 16)	75	10	41
32. For Structural Steel for Ships (A 12 – 16)	65	9	24
33. For Steel Castings (A 27 – 16)	73	18	
To increase the maximum phosphorus allowance 0.01 per cent in acid steel, in specifications:			
34. For Steel Castings (A 27 – 16)	75	17	23
35. For Welded Steel Pipe (A 53 –18)	62	0	53
II. PROPOSED REVISIONS IN TENTATIVE STANDARDS.			
36. For Tie Plates (A 67 – 18 T)	64	0	51
37. For Low-Carbon-Steel Track Plates (A 76 – 18 T)	62	0	53
38. For Steel Plates for Forge Welding (A 78 – 20 T)	70	0	45
39. For Boiler and Firebox Steel for Stationary Service (A 70 – 18 T)	69	0	46
40. For Carbon Tool Steel (A 71 – 20 T)	67	4	44
III. PROPOSED NEW TENTATIVE STANDARDS.			
41. For Cold-Drawn Steel Wire for Concrete Reinforcement	59	4	52
42. For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes	61	4	50
IV. TENTATIVE SPECIFICATIONS TO BE ADVANCED TO STANDARD.			
43. For Commercial Bar Steels (A 80 – 20 T), as amended	71	0	44

Total number of ballots cast	115
Number of members who failed to vote	10
Total membership	125

[a] In this column is recorded the number of votes cast as "Not Voting" on the various items.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

Rails, Splice Bars, Reinforcement Bars, Tie Plates, Track Bolts, and the Bessemer grade in Structural Steel for Buildings. The recommendation to remove the note from these specifications will require manufacturers to work to the original phosphorus limit for Bessemer steels.

Of the remaining specifications, three cover rivet steel, original sulfur 0.045 per cent; also the Specifications for Boiler Tubes and Seamless Tubes call for sulfur 0.045 per cent. The effect of this recommendation would be to require manufacturers to adhere to the original 0.045 limit.

Sulfur for Steel Chain (A 56) is specified at 0.05 per cent and this would again become the limit.

As against these changes cutting off the extension for sulfur and phosphorus, it is felt the extension in sulfur from 0.05 to 0.06 per cent in the three classes of structural steel must be retained due to the heavy tonnages involved, and to the continued difficulty in obtaining low-sulfur fuels and melting stock.

It will be noted that the sulfur extension will be removed on the materials which are to be worked hot and allowed on structural materials which are to be fabricated cold.

The recommendation to continue the extension of both phosphorus and sulfur in steel castings is made in the belief that the same difficulties with fuel and melting stock exist in this industry.

The movement which originated in the American Society for Testing Materials for a comprehensive survey of the effects of phosphorus and sulfur in steel is now well under way in the hands of a large and representative joint committee, working under the chairmanship of the Bureau of Standards. Our Society is looking to that investigation for final advice as to suitable limits, but until the work is completed it is believed that the changes now recommended may be made with safety.

STEEL RAILS AND ACCESSORIES (SUB-COMMITTEE I).

The work of Sub-Committee I during the past year has consisted in rewriting the present Standard Specifications for Carbon-Steel Rails (A 1 – 14), and the revision of Section 11 of the Standard Specifications for Quenched High-Carbon-Steel Splice Bars (A 49 – 15) and Section 10 of the Standard Specifications for Quenched Carbon-Steel Track Bolts (A 50 – 16). The rewriting of the Standard Specifications for Carbon-Steel Rails is one of form only, the most important change being the rewording of the section referring to the nick-and-break test. The purpose of this change was to clarify the meaning for the information of foreign buyers who are not as familiar with the nick-and-break test as are Americans. There is no change in the requirements of the test.

STRUCTURAL STEEL FOR BRIDGES, BUILDINGS AND ROLLING STOCK (SUB-COMMITTEE II).

The work of Sub-Committee II during the past year has consisted mainly in the revision of form of certain paragraphs in their specifications and the insertion of requirements for tension and bend test specimens for rivet bars which have been cold drawn, as well as revision of sections concerning bend test specimens for the purpose of harmonizing the various specifications affected.

STEEL REINFORCEMENT BARS (SUB-COMMITTEE V).

This committee has continued its work in cooperation with Committee C-2 on Reinforced Concrete on the subject of Specifications for Concrete Reinforcement Bars, but has been unable to come to an agreement in regard to the testing of deformed bars. It now appears as if this subject would have to be discussed by a separate joint committee, and Committee A-1 has reported to the Executive Committee that it would be agreeable to appoint representatives to serve on such a joint committee.

Sub-Committee V has also prepared new Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement, which are submitted for approval.[1]

STEEL FORGINGS AND BILLETS (SUB-COMMITTEE VI).

This sub-committee has made an investigation to ascertain whether there was a demand for a separate American Society for Testing Materials Specification for Ship Forgings and has concluded that no demand exists at this time sufficient to warrant the preparation of such specifications.

STEEL TUBING AND PIPE (SUB-COMMITTEE IX).

For some time past this sub-committee has been impressed with the desirability of having a single specification for all boiler tubes, and during the past year it appointed a sub-sub-committee to draw up recommendations for such a specification. This sub-sub-committee went into the matter very thoroughly with the idea of combining the three present American Society for Testing Materials Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes for Locomotives and Stationary Service into one general specification.

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[1] See p. 459.—ED.

They held an open meeting in Philadelphia on January 7, 1920, at which were present representatives of Sub-Committee IX of Committee A-1, Sub-Committee I of Committee A-2, American Society of Mechanical Engineers, American Railway Association, American Bureau of Shipping, Bureau of Engineering, U. S. N., seven manufacturers of boiler tubes and three representatives of locomotive builders. A draft of the proposed specification was presented at this meeting and thoroughly discussed, with the result that certain revisions were made and a subsequent open meeting held on January 12, 1921, with the representatives who were present at the previous meeting, and the modified proposed specifications again thoroughly discussed. The specifications as modified were then adopted by Sub-Committee IX and subsequently by Committee A-1, and are appended to this report.[1] The committee recommends that these specifications be approved as tentative.

In drafting these specifications the committee has had in mind preparing requirements that would be acceptable for stationary, locomotive and marine use, and would perhaps meet with the approval of the Boiler Code Committee of the American Society of Mechanical Engineers, of the American Railway Association, of the United States Steamboat Inspection Service, the various Marine Classification Societies, and the manufacturers of locomotive, stationary and marine boilers.

The committee has worked on the following plan: The basis taken was to be the minimum gage system of ordering which is now the general practice for stationary and marine use, whereas the present locomotive basis is to allow a tolerance below the specified gage, and to meet the requirements of locomotive practice an over-gage limit has been provided. In working up the specifications on this plan nothing has been omitted that will sacrifice quality. It provides, in effect, for locomotive tubes to be ordered in accordance with stationary and marine practices. The relatively lesser tonnage of locomotive tubes seemed to the committee to justify this action.

In order that the attention of consumers may be drawn to the change in the system of tolerances on gage thickness which affects the users of locomotive tubes, and also that the marine and stationary interests may be advised that no change has been made in their former practice, your committee recommends that the specifications be introduced by the following explanatory note:

"In the following specifications attention is called to the basis on which tubes are gaged for thickness. No variation beneath the ordered gage is allowed, all variations being on the side of thicker than ordered gage. Present standard A.S.T.M. specifications for locomotive tubes permit of variation above and below the ordered gage. The present A.S.T.M. standard specifications for stationary service, as well as Boiler Code and Marine specifications, do not permit of tubes being less than the ordered gage. Where previously used specifications permit of tubes less than the ordered gage, the purchaser in using these tentative specifications must order tubes one gage lighter than formerly to obtain the same weight and gage of tubes. For example: where 2 in. o.d. No. 11 B.w.g. cold-drawn tubes were previously ordered, 2 in. o.d. No. 12 B.w.g. should be ordered to these specifications. Tubes would be furnished which would have an average thickness of No. 11 B.w.g. They would not be less than No. 12 B.w.g. but might be No. 10 B.w.g. They would have the same nominal weight as under the previous system."

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[1] See p. 461.—ED.

The committee also recommends certain changes in the Standard Specifications for Lap-Welded and Seamless Steel Boiler Tubes for Stationary Service (A 28-18) and Standard Specifications for Welded[1] Steel Pipe (A 53-18), as indicated in the Appendix.

AUTOMOBILE STEELS (SUB-COMMITTEE X).

Sub-Committee X has made some revisions of the Standard Specifications for Automobile Carbon and Alloy Steels (A 29-18), including a change in the wording of the process clause and modifications of Tables II, III and IV, the insertion of a new table which is numbered VI, and the number of the present Table VI changed to VII. These modifications have been made in order to bring the chemical compositions in harmony with those of the specifications of the Society of Automotive Engineers.

BOILER STEEL (SUB-COMMITTEE XI).

As a result of a conference between representatives of our Society and the American Society of Mechanical Engineers' Boiler Code Committee for the purpose of harmonizing specifications, certain tentative changes were agreed upon. These proposed changes have been given consideration by Sub-Committee XI and they have recommended the revisions of the Specifications for Boiler and Firebox Steel for Stationary Service (A 70-18 T) and the Specifications for Boiler and Firebox Steel for Locomotives (A 30-18) which are submitted herewith.

These changes represent all that this committee is prepared to recommend at this time, but it is understood that the Society's representatives will continue their cooperation with the American Society of Mechanical Engineers' Boiler Code Committee to the end that the specifications will eventually be in complete harmony.

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[1] Revised to include Seamless Steel Pipe.

METHODS OF CHEMICAL ANALYSIS (SUB-COMMITTEE XII).

Sub-Committee XII has made considerable progress in the investigation on ladle test ingots, and has collected material to continue the investigation of the influence of aluminum treatment of test ingots on segregation and physical soundness, and is now actively bringing its studies to completion.

METHODS OF TESTING (SUB-COMMITTEE XIII).

Sub-Committee XIII is organizing for the prosecution of work on the revision of methods of tests now included on our present standards and the preparation of new methods of test. The chairman of this sub-committee is also the representative of Committee A-1 on Committee E-1 on Methods of Testing and will keep in close touch with the progress of the work of this latter committee.

COMMERCIAL BAR STEELS (SUB-COMMITTEE XV).

This sub-committee has considered some criticisms of the Tentative Specifications for Commercial Bar Steels (A 80 – 20 T), and in order to create a more marked distinction between commercial bar steels and special kinds, such as are subject to check analysis within close limits, it has made a revision of Table II of the tentative specification as given in the attached Appendix.

NOMENCLATIRE AND DEFINITIONS (SUB-COMMITTEE XVIII).

This sub-committee has been organized, but at the present time has no specific subjects or problems before it. It is prepared to cooperate with Committee E-8 on Nomenclature and Definitions as soon as this committee has completed its organization.

This report has been submitted to letter ballot of the committee, which consists of 125 members, of whom 100 have voted affirmatively, 1 negatively, and 24 have refrained from voting.

Respectfully submitted on behalf of the committee.

F. M. WARING,
Chairman and Temporary Secretary.

For Addendum to this report, see p. 87.

APPENDIX.

PROPOSED REVISIONS OF STANDARDS AND TENTATIVE STANDARDS FOR STEEL.

In this appendix are given proposed revisions in certain standard and tentative specifications, which, for convenience, are numbered from 1 to 43, inclusive, to correspond to the report of the committee. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

PROPOSED REVISIONS IN STANDARDS.

No. 1.—STANDARD SPECIFICATIONS FOR CARBON-STEEL RAILS: A 1 - 14.[1]

These specifications have been extensively revised as to form, at the same time, clarifying the sections covering the nick-and-break test.

No. 2.—STANDARD SPECIFICATIONS FOR QUENCHED HIGH-CARBON-STEEL SPLICE BARS: A 49 - 15.[1]

Section 11.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "If the results of the physical tests of any test lot do not conform to the requirements specified, the manufacturer may retreat such lot one or more times [and retests shall be made as specified in section 10] *in which case two additional tension and two additional bend tests shall be made from such lot, all of which shall conform to the requirements specified.*"

No. 3.—STANDARD SPECIFICATIONS FOR QUENCHED CARBON-STEEL TRACK BOLTS: A 50 - 16.[1]

Section 1 (b).—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel for the nuts shall be made by [the Bessemer or open-hearth process] *either or both the following processes: Bessemer or open-hearth.*"

Section 10.—Change to read as follows by the addition of the italicized words:

> "If the results of the physical tests of any test lot do not conform to the requirements specified, *the manufacturer may retreat such lot one or more times in which case* two additional tension and two additional bend tests shall be made from such lots, all of which shall conform to requirements specified."

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[1] **1918 Book of A.S.T.M. Standards.**

Section 11.[1]—Change to read as follows:

> "The bolts and nuts shall conform to the dimensions specified by the purchaser. They shall be neatly formed and free from fins or nicking. The head of the bolt shall be concentric with and firmly joined to the shank, with the underside at right angles to the axis of the bolt. The threads shall be sharp and true to gage and of the design specified by the purchaser. The nuts shall have a hand free fit on the bolt from two to six turns, and wrench tight the balance of the screw length without distorting the threads or twisting the shank. They shall be screwed on the bolts before packing, a sufficient number of turns to hold them in place until used. A variation of $\frac{1}{32}$ in. under and $\frac{1}{64}$ in. over the specified diameter of the shank of the bolt will be permitted. The diameter of rolled thread shall not exceed the diameter of the shank more than $\frac{1}{16}$ in. for bolts $\frac{7}{8}$ in. in diameter and under, nor more than $\frac{3}{32}$ in. for bolts 1 in. in diameter and over. The outside diameter of the finished rolled thread shall not exceed the diameter of the shank of a cut thread bolt of corresponding size. The length of the bolt under the head shall not vary more than $\frac{1}{8}$ in. from that specified. A variation in the dimensions of the elliptical shoulders under the head of $\frac{1}{32}$ in. and a taper of the shoulder of $\frac{1}{32}$ in. will be permitted."

No. 4.—Standard Specifications for Steel Track Spikes: A 65 – 18.[2]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel [may] *shall* be made by [the Bessemer or open-hearth process] *either or both the following processes: Bessemer or open-hearth.*"

No. 5.—Standard Specifications for Steel Screw Spikes: A 66 – 18.[2]

Section 1.—Make the same change as in Section 1 of Specifications A 65 – 18 above.

No. 6.—Standard Specifications for Low Carbon Steel Splice Bars: A 3–14.[2]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel [may] *shall* be made by [the Bessemer, open-hearth or any other process approved by the purchaser] *either or both the following processes: Bessemer or open-hearth.*"

No. 7.—Standard Specifications for Quenched Alloy Steel Track Bolts: A 51 – 16.[2]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

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[1] Revision submitted as tentative in 1920.

[2] 1918 Book of A.S.T.M. Standards.

"The steel for the bolts shall be made by [the open-hearth or electric process] *either or both the following processes: open-hearth or electric furnace.*

"The steel for the nuts shall be made by [the Bessemer or open-hearth process] *either or both the following processes: Bessemer or open-hearth.*"

NO. 8.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BRIDGES: A 7 - 16.[1]

Section 9.—Change to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.

"(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*), (*e*) and (*f*) shall be of the full thickness or diameter of material as rolled.

"(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel; except that bend test specimens for eyebar flats may have three rolled sides.

"(*d*) Tension test specimens for plates and eyebar flats over 1½ in. in thickness, and bend test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

"(*e*) Test specimens for bars over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by ½ in. in section.

"(*f*) Tension test specimens for pins and rollers shall conform to the dimensions shown in Fig. 2. In this case, the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens shall be 1 by ½ in. in section.

"(*g*) The tension test specimen shown in Fig. 2 and the 1 by ½-in. bend test specimen for pins and rollers shall be taken so that the axis is 1 in. from the surface; and for other bars over 1½ in. in thickness or diameter, midway between the center and surface.

"(*h*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

"(*i*) Test specimens for rivet bars which have been cold drawn shall be normalized before testing."

NO. 9.—STANDARD SPECIFICATIONS FOR STRUCTURAL NICKEL STEEL: A 8 - 16.[1]

Section 6 (a).—Change the term "eyebar" to read "eyebar flats" at the head of columns 4 and 5 in the table of tensile properties and in the note at the bottom of this table.

Section 11.—Change to read the same as Section 9 of Specifications A 7-16 above.

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[1] 1918 Book of A.S.T.M. Standards.

NO. 10.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR BUILDINGS: A 9 – 16.[1]

Section 1 (a).—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "Structural steel, except as noted in Paragraph (*b*), [may] *shall* be made by [the Bessemer or the open-hearth] *either or both the following processes: Bessemer or open-hearth.*"

Section 8.—Change so that the new Section 8 will read as follows:

(*a*).—To read the same as Section 9 (*a*) of Specifications A 7 – 16 above.

(*b*).—To read the same as Section 9 (*b*) of Specifications A 7 – 16 above.

(*c*).—To read as follows:

> "Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel."

(*d*).—To read as follows:

> "Test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in."

Sections 8 (*e*), (*f*), (*g*), (*h*) *and* (*i*).—To read the same as Sections 9 (*e*), (*f*), (*g*), (*h*) and (*i*) of Specifications A 7 – 16 above.

NO. 11.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR LOCOMOTIVES: A 10 – 16.[1]

Section 3.—Increase the sulfur requirement of 0.05 per cent to 0.06 per cent. (*This revision is Item No. 30 in the ballot.*)

Section 9.—Change to read as follows:

> "9. (*a*) Test specimens shall be prepared for testing from the material in its rolled or forged condition, except when it is specified to be annealed; in which case the test specimens shall be prepared from the material as annealed for use, or from a short length of a full section similarly treated.
>
> "(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraphs (*d*) and (*e*), shall be of the full thickness or diameter of material as rolled.
>
> "(*c*) Test specimens for plates, shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.
>
> "(*d*) Test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of least 9 in.
>
> "(*e*) Test specimens for bars over 1½ in. in thickness or diameter may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9

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[1] 1918 Book of A.S.T.M. Standards.

in.; or tension test specimens may conform to the dimensions shown in Fig. 2, in which case the ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial. Bend test specimens may be 1 by ½ in. in section.

"(*f*) The tension test specimen shown in Fig. 2 and the 1 by ½ in. bend test specimen for bars over 1½ in. in thickness or diameter shall be taken so that the axis is midway between the center and surface.

"(*g*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in."

NO. 12.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR CARS: A 11 - 16.[1]

Section 3.—Increase the sulfur requirement of 0.05 per cent to 0.06 per cent (Structural grade only). (*This revision is Item No. 31 in the ballot.*)

Section 9.—Change to read the same as Section 9 of Specifications A 10 - 16 above, with the insertion of an additional Paragraph (*h*) to read the same as Paragraph (*i*) of Specifications A 7 - 16 above.

NO. 32.—STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR SHIPS: A 12 - 16.[1]

Section 2.—Increase the sulfur requirement of 0.05 per cent to 0.06 per cent.

NO. 13.—STANDARD SPECIFICATIONS FOR CARBON-STEEL BARS FOR RAILWAY SPRINGS: A 14-16.[1]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel [may] *shall* be made by [the open-hearth, crucible or electric process] *one or more of the following processes: open-hearth, crucible or electric furnace.*"

NO. 14.—STANDARD SPECIFICATIONS FOR CARBON-STEEL BARS FOR RAILWAY SPRINGS WITH SPECIAL SILICON REQUIREMENTS: A 68 - 18.[1]

Section 2.—Make the same change as in Section 2 of Specifications A 14 - 16 above.

NO. 15.—STANDARD SPECIFICATIONS FOR CARBON-STEEL BARS FOR VEHICLE AND AUTOMOBILE SPRINGS: A 58 - 16.[1]

Section 2.—Make the same change as in Section 2 of Specifications A 14 - 16 above.

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[1] 1918 Book of A.S.T.M. Standards.

NO. 16.—STANDARD SPECIFICATIONS FOR SILICON MANGANESE STEEL BARS FOR AUTOMOBILE AND RAILWAY SPRINGS: A 59 – 16.[1]

Section 2.—Make the same change as in Section 2 of Specifications A 14 – 16 above.

NO. 17.—STANDARD SPECIFICATIONS FOR CHROME-VANADIUM-STEEL BARS FOR AUTOMOBILE AND RAILWAY SPRINGS: A 60 – 16.[1]

Section 2.—Make the same change as in Section 2 of Specifications A 14 – 16 above.

NO. 18.—STANDARD SPECIFICATIONS FOR BILLET-STEEL CONCRETE REINFORCEMENT BARS: A 15 – 14.[1]

Section 3 (a).—Make the same change as in Section 1 of Specifications A 65 – 18 above.

NO. 19.—STANDARD SPECIFICATIONS FOR CARBON-STEEL AND ALLOY-STEEL BLOOMS, BILLETS AND SLABS FOR FORGINGS: A 17 – 18.[1]

Section 4.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel [may] *shall* be made by [the open-hearth or any other process approved by the purchaser] *either or both the following processes: open-hearth or electric furnace.*"

NO. 20.—STANDARD SPECIFICATIONS FOR CARBON-STEEL AND ALLOY-STEEL FORGINGS: A 18 – 18.[1]

Section 2.—Make the same change as in Section 4 of Specifications A 17 – 18 above.

NO. 21.—STANDARD SPECIFICATIONS FOR QUENCHED-AND-TEMPERED CARBON-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS: A 19 – 18.[1]

Section 2.—Make the same change as in Section 4 of Specifications A 17 – 18 above.

NO. 22.—STANDARD SPECIFICATIONS FOR QUENCHED-AND-TEMPERED ALLOY-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS: A 63 – 18.[1]

Section 2.—Make the same change as in Section 4 of Specifications A 17 – 18 above.

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[1] 1918 Book of A.S.T.M. Standards.

NO. 23.—STANDARD SPECIFICATIONS FOR CARBON-STEEL FORGINGS FOR LOCOMOTIVES: A 20 – 16.[1]

Section 3.—Make the same change as in Section 4 of Specifications A 17 – 18 above.

NO. 24.—STANDARD SPECIFICATIONS FOR COLD-ROLLED STEEL AXLES: A 22 – 16.[1]

Section 1 (a).—Make the same change as in Section 4 of Specifications A 17 – 18 above.

NO. 25.—STANDARD SPECIFICATIONS FOR STEEL CASTINGS: A 27 – 16.[1]

Section 4.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel [may] ***shall*** be made by [the open-hearth, crucible, or any other process approved by the purchaser] ***one or more of the following processes: open-hearth, electric furnace, side-blow converter or crucible.***"

Section 6.—Change to read as follows by the addition of the italicized words and figures and the omission of the words and figures in brackets: (*The revision is covered by Items Nos. 33 and 34 in the ballot.*)

> "The castings shall conform to the following requirements as to chemical composition:

		CLASS A.	CLASS B.
Carbon		not over 0.30 per cent	....
Phosphorus	*Acid*	" " *0.07* "	not over *0.06* per cent
	Basic	" " 0.06 "	" " 0.05 "
Sulfur		" "	[0.05] *0.06* "

NO. 26.—STANDARD SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL BOILER TUBES FOR LOCOMOTIVES: A 28 – 18.[1]

Section 6.[2]—Omit the word "small" before "tubes" in Paragraphs (*a*) and (*b*), In Paragraph (*a*) omit the comma after the word "pipes."

Section 13.—Change from its present form: namely,

> "The weight of the tubes shall not vary more than 5 per cent from that specified in Table I."

to read as follows:

> "The weight of cold-drawn seamless tubes shall vary not more than 5 per cent above or below that specified in Table I.

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[1] 1918 Book of A.S.T.M. Standards.

[2] Revision submitted as tentative in 1920.

"The weight of hot-finished tubes under 3½ in. outside diameter shall vary not more than 5 per cent above or below that specified in Table I. Tubes 3½ in. and larger in outside diameter may vary 2½ per cent below and 7½ per cent above that specified."

Section 14.—Change from its present form: namely,

"(*a*) The finished tubes shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered.

"(*b*) The thickness at any point shall not vary more than 1 gage above or 1 gage below that specified. In the case of boiler tubes which are expanded and swaged, the thickness of the expanded end may be 1½ gages lighter and of the swaged end 2 gages heavier than the thickness specified.

"(*c*) The length shall not be less, but may be 0.125 in. more than that ordered."

to read as follows:

"(*a*) Finished tubes 3½ in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall vary not more than 0.015 in. from the size ordered. For tubes over 3½ in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

"(*b*) The thickness of cold-drawn tubes at any point shall vary not more than 1 gage above or 1 gage below that specified.

"(*c*) The thickness of hot finished tubes at any point shall not exceed two gages above or one gage below that specified, but in all cases the weight variation shall be within that specified in Paragraph 13 (*b*). In the case of boiler tubes that are expanded and swaged, the thickness of the expanded end may be 1½ gages lighter and the swaged end three gages heavier than the thickness specified.

"(*d*) The length shall be not less, but may be 0.125 in. more than that ordered."

NO. 27.—STANDARD SPECIFICATIONS FOR AUTOMOBILE CARBON AND ALLOY STEELS: A 29-18.[1]

Section 3.—Change from its present form: namely,

"The steels may be made by the Bessemer, open-hearth, crucible, electric, or any other process approved by the purchaser."

to read as follows:

"The steels may be made by one or more of the following processes: Open-hearth, crucible or electric furnace; except that screw stock shall be made by the Bessemer or the open-hearth processes as specified."

Table II—

Add to the present table the two following compositions and one foot note.

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[1] 1918 Book of A.S.T.M. Standards.

	Desired.	Permissible Range.	Desired.	Permissible Range.
Carbon	0.45	0.40 – 0.50	....	not over 0.17
Manganese	0.65	0.50 – 0.80	0.45	0.30 – 0.60
Phosphorus	....	not over 0.04	....	not over 0.04
Sulfur	....	" " 0.045	....	" " 0.045
Nickel	3.50	3.25 – 3.75	Note "*a*"	4.50 – 5.25

(*a*) When parts made of this steel are to be machined after carbonization, the Nickel shall be close to the lower limit.

Table III (with 1.25 per cent nickel).—

Add a footnote to the five permissible ranges of Chromium, reading:

"Another type of these five grades of steel is available with Chromium 0.30 desired, permissible range 0.15 – 0.45.

Table IV—

Change the permissible range in chromium in the first three classes from 0.65 – 0.85 to 0.60 – 0.90 per cent, leaving the desired chromium 0.75 per cent as before.

Omit the fourth, fifth and seventh classes in the table and substitute therefor the following fully representative type of oil-quenching chromium steel:

	Desired.	Permissible Range.
Carbon, per cent	1.00	0.95 – 1.10
Manganese, "	0.35	0.20 – 0.50
Phosphorus, "	....	not over 0.03
Sulfur, "	....	" " 0.03
Chromium, "	1.35	1.20 – 1.50

Omit the sixth chemical composition with desired Carbon 0.95.

Table VI—

Change the number of the present Table VI to VII and substitute the following Table VI:

TABLE VI.—AUTOMOBILE CHROMIUM-TUNGSTEN STEELS.

Carbon.		Manganese, not over	Phosphorus, not over	Sulfur, not over	Chromium.		Tungsten.	
Desired.	Permissible Range.				Desired.	Permissible Range.	Desired.	Permissible Range.
0.60	0.50 – 0.70	0.30	0.035	0.035	3.50	3.00 – 4.00	13.00	12.00 – 15.00
0.60	0.50 – 0.70	0.30	0.035	0.035	3.50	3.00 – 4.00	16.00	15.00 – 18.00
0.60	0.50 – 0.70	0.30	0.035	0.035	0.75	0.50 – 1.00	1.75	1.50 – 2.00

No. 28.—Standard Specifications for Boiler and Firebox Steel for Locomotives: A 30 – 18.[1]

Section 3.—Change the present requirements as to chemical composition for firebox steel: namely,

		Firebox.
Carbon		0.12 – 0.25 per cent
Manganese		0.30 – 0.60 "
Phosphorus	Acid	not over 0.04 "
	Basic	" " 0.035 "
Sulfur		" " 0.04 "

to conform to the following:

Carbon	for plates ¾ in. or under in thickness	0.12 – 0.25 per cent
	for plates over ¾ in. in thickness	0.12 – 0.30 "
Manganese	for plates ¾ in. or under in thickness	0.30 – 0.50 "
	for plates over ¾ in. in thickness	0.30 – 0.60 "
Phosphorus	Acid	not over 0.04 "
	Basic	" " 0.035 "
Sulfur		" " 0.04 "

Section 7 (a).—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "For material over ¾ in. in thickness a deduction [of 0.5] from the percentages of elongation specified in Section 6 (*a*) *of 0.125 per cent* shall be made for each increase of [⅛ in. in] *$^1/_{32}$ in. of the specified* thickness above ¾ in."

No. 35.—Standard Specifications for Welded Steel Pipe: A 53 – 18.[1]

A revision in the form of new tentative specifications was presented a year ago and printed in the *Proceedings*, Vol. XX, Part I (1920), under the Serial Designation: A 53 – 20 T. These Tentative Specifications have since been revised and are appended[2] in amended form for adoption as standard.

PROPOSED REVISIONS IN TENTATIVE STANDARDS.

No. 36.—Tentative Specifications for Steel Tie Plates: A 67 – 20 T.[3]

Section 2.—Make the same change as in Section 1 of Specifications A 65 – 18 above.

No. 37.—Tentative Specifications for Low-Carbon-Steel Track Bolts: A 76 – 20 T.[3]

Section 1 (a).—Make the same change as in Section 1 of Specifications A 65 – 18 above.

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[1] 1918 Book of A.S.T.M. Standards.

[2] See 1921 Book of A.S.T.M. Standards.—Ed.

[3] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

NO. 38.—TENTATIVE SPECIFICATIONS FOR STEEL PLATES FOR FORGE WELDING: A 78 - 20 T.[1]

Section 2.—Change to read as follows by the omission of the words in brackets:

"The steel shall be made by the open-hearth [or any other] process [approved by the purchaser]."

Section 9.—Change from its present form: namely,

"Tension and bend test specimens shall be taken from the finished rolled material.

"Tension and bend test specimens except as specified in Paragraph (*c*) shall be of the full thickness of material as rolled; and may be machined to the form and dimensions shown in Fig. 1 or with both edges parallel.

"Tension and bend test specimens for plates over 1½ in. in thickness may be machined to a thickness of at least ¾ in. for a length of at least 9 in."

to read as follows:

"(*a*) Test specimens shall be prepared for testing from the material in its rolled condition.

"(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraph (*c*) shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

"(*c*) Test specimens for plates over 1½ in. in thickness may be machined to a thickness or diameter of at least ¾ in. for a length of at least 9 in.

"(*d*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in."

NO. 39.—TENTATIVE SPECIFICATIONS FOR BOILER AND FIREBOX STEEL FOR STATIONARY SERVICE: A 70 - 18 T.[1]

Section 3.—Change the present requirements for manganese for firebox steel from 0.30–0.60 per cent, to read as follows:

For plates ¾ in. or under in thickness..........	0.30 - 0.50 per cent
" " over ¾ in. in thickness..............	0.30 - 0.60 "

Section 6 (a).—Revise the note "but for firebox steel not less than 24 per cent, subject to the modifications of Section 7," now appearing under this section, making the note into a new Paragraph (*b*) reading as follows:

"Should the above rule for minimum allowable elongation give a value of less than 24 per cent for firebox steel, the minimum allowable elongation shall be 24 per cent, subject to the modifications of Section 7."

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

Section 7 (a).—Change to read as follows by the addition of the italicized words and figures and the omission of the words and figures in brackets:

> "For material over $\frac{3}{4}$ in. in thickness a deduction [of 0.5] from the percentages of elongation specified in Section 6 (*a*) *of 0.125 per cent* shall be made for each increase of [$\frac{1}{8}$ in. in] *$^{1}/_{32}$ in. of the specified* thickness above $\frac{3}{4}$ in. to a minimum of 20 per cent."

Section 14.—Omit Paragraphs (*b*), (*c*) and (*d*).

No. 40.—TENTATIVE SPECIFICATIONS FOR CARBON TOOL STEEL: A 71 - 20 T.[1]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The steel shall be made by [the crucible or electric process,] *either or both of the following processes: crucible or electric,* with the exception of [Grade] *Class* C which may *also* be made by the open-hearth process."

No. 43.—TENTATIVE SPECIFICATIONS FOR COMMERCIAL BAR STEELS: A 80 - 20 T.[1]

Table II.—Amend the columns for permissible variations in carbon to read as follows:

	PERMISSIBLE VARIATIONS.	
OPEN-HEARTH GRADES.	UNDER.	OVER.
Dead Soft and Soft	....	0.03
15-25	0.02	0.05
20-30	0.03	0.06
25-40	0.03	0.07
35-50	0.03	0.08
BESSEMER GRADES.		
Welding and Soft	....	0.03
15-25	0.02	0.05
25-40	0.03	0.07
35-50 and 40-60	0.05	0.08

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920.)

ADDENDUM TO REPORT OF COMMITTEE A-1.

At a meeting of Committee A-1 held on Wednesday, June 22, 1921, prior to the presentation of its annual report to the Society, Sub-Committee VI on Forgings recommended the following revisions in the specifications under its jurisdiction to be submitted to the Society in connection with the printed report of the committee.

STANDARD SPECIFICATIONS FOR CARBON-STEEL AND ALLOY-STEEL FORGINGS: A 18 - 18.[1]

Section 6.—Change to read as follows:

"6. Heat treatment, if required, shall consist of either annealing or quenching and tempering, as specified.

"(*a*) The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformily.

"(*b*) The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly."

STANDARD SPECIFICATIONS FOR QUENCHED-AND-TEMPERED CARBON-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS: A 19 - 18.[1]

Section 6.—Change to read as follows:

"The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformily reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly."

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[1] 1918 Book of A.S.T.M. Standards.

STANDARD SPECIFICATIONS FOR QUENCHED-AND-TEMPERED ALLOY-STEEL AXLES, SHAFTS, AND OTHER FORGINGS FOR LOCOMOTIVES AND CARS: A 63 – 18.[1]

Section 6.—Change to read as follows:

> "The procedure to be followed in quenching and tempering shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as a "quenching charge"), and quenched in some medium under substantially uniform conditions for each quenching charge. Finally, they shall be uniformly reheated to the proper temperature for tempering or "drawing back" (a group thus reheated being known as a "tempering charge"), and allowed to cool uniformly."

STANDARD SPECIFICATIONS FOR CARBON-STEEL FORGINGS FOR LOCOMOTIVES: A 20 – 16.[1]

Section 6.—Change to read as follows:

> "The procedure to be followed in annealing shall consist in allowing the objects, immediately after forging, to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling. They shall then be uniformly reheated to the proper temperature to refine the grain (a group thus reheated being known as an "annealing charge"), and allowed to cool uniformly."

Respectfully submitted,
F. M. WARING,
Chairman and Temporary Secretary.

EDITORIAL NOTE.

The proposed revisions of the standard specifications referred to under item (*a*) on page 67 as presented in 1919, the proposed revisions of the eleven standard specifications referred to under item (*b*) on page 67 as presented in 1920, the proposed revisions of the three specifications referred to under item (*c*) on page 67 as presented in 1920 and subsequently amended as indicated in the Appendix, and the proposed revisions of the standard specifications listed as items Nos. 1–35 in the Appendix, and in the table on analysis of votes, page 69, in their further revised form as indicated in the Addendum, were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The specifications as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The proposed revisions in the five tentative specifications referred to in this report as items Nos. 36 to 40, pages 84 to 86, were accepted.

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[1] 1918 Book of A.S.T.M. Standards.

The proposed Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement and the proposed Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes were accepted for publication as tentative and appear on pages 459–467.

The Tentative Specifications for Commercial Bar Steels as amended were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE A-2

ON

WROUGHT IRON.

During the year the committee has held three meetings.

The committee has cooperated with Committee A-1 in writing new specifications for tubes which include both steel and charcoal-iron tubes and has approved those portions of them which apply to iron tubes. These combined Specifications will be presented by Committee A-1. The committee also submits revisions in the Specifications for Charcoal-Iron Boiler Tubes (A 38 – 18). These revisions will harmonize these specifications with the specifications for Steel Boiler Tubes (A 28 – 18) at the same time preserving the test for Charcoal-Iron Boiler Tubes.

The specifications for Welded Wrought Iron Pipe (A 72 – 18) have been revised to make certain minor requirements conform to similar sections in the Tentative Specifications for Steel Pipe (A 53 – 20 T) as revised.

The committee has prepared a consolidation of the specifications for Staybolt Iron (A 39 – 18), Engine Bolt Iron (A 40 – 18) and Extra Refined Wrought-Iron Bars (A 79 –19 T) as a change in form only for the sake of economy in publication. This consolidation will replace these three specifications as printed separately.

Hollow staybolt iron is now quite generally used for certain parts of locomotive boilers, and needs recognition in our specifications. Partly due to the structure of the iron and partly due to the difficulties involved in testing a hollow bar, the requirements of the present Standard Specifications for Staybolt Iron (A 39 – 18) are not quite adapted to the hollow product, therefore separate specifications have been written as appended hereto.[1]

During the past few years a considerable change has taken place in the process of manufacture of some of the ordinary grades of bar iron. Small sizes of mixed scrap, thoroughly reworked, are now a prominent factor and it has been thought desirable to recognize this condition in a new specification, rather than to include the material in our present Standard Specifications for Refined Wrought-Iron Bars (A 41 – 18). These specifications present the same tensile and bend test requirements as for the refined bars, but the section on manufacture is particularly adapted to this product.

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[1] See p. 478.—Ed.

Proposed revisions in the requirements for tensile properties of Engine Bolt Iron (A 40 – 18) are offered. The present standard specifications are now being applied to much larger sizes than was originally intended. The revision provides workable requirements for the larger bars.

The Standard Specifications for Iron and Steel Chain (A 56 – 18) have received very careful study during the year in cooperation with a special committee of the manufacturers. While the present specification is substantially correct with respect to test requirements, gradual changes in raw material, and in trade practices, have made necessary a thorough revision of the sections on classification and manufacture. The new specifications are appended.[1] Especial attention is directed to the term "Crane Chain," which no longer represents the highest grade, the term "Dredge Chain" having superseded it.

The Tentative Specifications for Extra Refined Wrought-Iron Bars (A 79 – 19 T) have been slightly revised with respect to yield point. The original requirement for light bars appears in the light of later experience to be too rigid.

Sub-Committees on Nomenclature and Definitions and on Methods of Testing have been organized.

PROPOSED REVISIONS OF STANDARDS.

1. *Specifications for Staybolt Iron* (*A 39 – 18*).[2]—It is recommended that the tentative change in tolerances for diameter of bars of Staybolt Iron submitted in 1920 be made standard.

2. *Specifications for Welded Wrought-Iron Pipe* (*A 72 – 18*).[2]—It is recommended that the appended[3] revised specifications be submitted to the Society for adoption as standard. Letter ballot vote of the committee on this recommendation is as follows: Affirmative, 26; negative, 0; not voting, 13.

3. *Specifications for Lap-Welded Charcoal-Iron Boiler Tubes for Locomotives* (*A 38 – 18*).[2]—It is recommended that the appended revisions be submitted to the Society for adoption as standard. The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 26; negative, 1; not voting, 12.

4. *Specifications for Engine-Bolt Iron* (*A 40 – 18*).[2]—It is recommended that the revision given in the appendix be submitted to the Society for adoption as standard for publication in the 1921 Book of Standards, provided the recommendation receives the necessary nine-tenth vote at the annual meeting. The letter ballot vote of the

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[1] See page 468.—ED.

[2] 1918 Book of A.S.T.M. Standards.

[3] See 1921 Book of A.S.T.M. Standards.—ED.

committee on this recommendation is as follows: Affirmative, 29; negative 2; not voting, 8.

It is also recommended that the tentative revision submitted in 1919 be made standard. This revision inserts the words "all pig" before "puddled iron" in Section 1.

5. *Specifications for Iron and Steel Chain* (*A 56 - 18*).[1]—It is recommended that the present standard specifications be withdrawn and that the revised specifications be accepted for publication as tentative. The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 28; negative, 1; not voting, 10.

TENTATIVE SPECIFICATIONS TO BE ADVANCED TO STANDARD.

6. *Extra Refined Wrought-Iron Bars* (*A 79 - 19 T*).[2]—It is recommended that these specifications be submitted to the Society for advancement to standard as amended. The amendment, as given in the appendix brings the requirements for yield point in conformity with the revised requirements for yield point of the Standard Specifications for Engine-Bolt Iron (A 40 - 18). The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 30; negative, 2; not voting, 7.

7. *Definitions of Terms Relating to Wrought-Iron Specifications* (*A 81 - 20 T*).[3]—It is recommended that these definitions be submitted to the Society for advancement to standard. The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 31; negative, 0; not voting, 8.

PROPOSED NEW STANDARDS.

8. *Merchant Bar Iron.*—It is recommended that these Proposed Tentative Specifications for Merchant Bar Iron as appended hereto[4] be accepted as tentative. The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 27; negative, 3; not voting, 9.

9. *Hollow Staybolt Iron.*—It is recommended that these Proposed Tentative Specifications for Hollow Staybolt Iron as appended hereto[5] be accepted as tentative. The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 29; negative, 1; not voting, 9.

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[1] 1918 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 522 (1920).

[3] *Proceedings*, Am. Soc. Test. Mat., Vol. XX, Part I, p. 526 (1920).

[4] See p. 474.—ED.

[5] See p. 478.—ED.

This report has been referred to letter ballot of the committee which consists of 39 members, of whom 34 have voted affirmatively, none negatively and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. E. SMITH,
Chairman.

J. B. YOUNG,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Engine-Bolt Iron as presented in 1919 and subsequently revised as given in the Appendix to this report, the proposed revisions of the Standard Specifications for Staybolt Iron as presented in 1920 and the proposed revisions of the Standard Specifications for Welded Wrought-Iron Pipe and of the Standard Specifications for Lap-Welded Charcoal-Iron Boiler Tubes for Locomotives as given in the Appendix to this report were approved at the annual meeting and adopted by letter ballot vote of the Society on August 20, 1921. The specifications as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The proposed revisions of the Standard Specifications for Iron and Steel Chain were accepted for publication as new tentative specifications and appear on pages 468–473. The standard specifications were accordingly withdrawn.

The Tentative Definitions of Terms Relating to Wrought-Iron Specifications referred to in this report were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards. The Tentative Specifications for Extra Refined Wrought-Iron Bars as amended were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921. In accordance with the recommendations of the committee these specifications have been combined with the Standard Specifications for Staybolt Iron and the Standard Specifications for Engine-Bolt Iron and appear in the 1921 Book of A.S.T.M. Standards under the title Standard Specifications for Staybolt, Engine Bolt and Extra Refined Wrought-Iron Bars, with the Serial Designation: A 84 – 21.

The proposed Tentative Specifications for Merchant Bar Iron and the proposed Tentative Specifications for Hollow Staybolt Iron were accepted for publication as tentative and appear on pages 474–480.

APPENDIX.

PROPOSED REVISIONS OF STANDARDS AND TENTATIVE STANDARDS FOR WROUGHT IRON.

STANDARD SPECIFICATIONS FOR LAP-WELDED CHARCOAL-IRON BOILER TUBES FOR LOCOMOTIVES (A 38 – 18).[1]

1. *Section 5.*—Change from its present form namely:

"A test specimen 2½ in. in length shall stand crushing longitudinally to a height of 1⅛ in. without splitting in either direction and without cracking or opening at the weld."

to read as follows:

"A test specimen 2½ in. in length shall withstand crushing longitudinally without splitting, cracking or opening at the weld as follows: Tubes 10 Bwg. or lighter to a height of 1⅛ in., if heavier that 10 Bwg. to a height of 1¾ in."

TABLE I.—STANDARD WEIGHTS FOR LAP-WELDED CHARCOAL-IRON BOILER TUBES FOR LOCOMOTIVES.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

Thickness.		Weight, lb. per Foot of Length, Outside Diameter, in.													
In.	B.w.g.	1¾	1⅞	2	2¼	2½	3	3½	4	4½	5	5¼	5⅜	5½	6
0.095	13	1.679	1.806	1.932	2.186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
0.109	12	1.910	2.055	2.201	2.492	2.783	3.365		.....	.....	.....	.....	.....	.....	.....
0.120	11	2.089	2.249	2.409	2.729	3.050	3.691	4.331	.....	.....	.....	.....	.....	.....	.....
0.134	10	2.312	2.491	2.670	3.028	3.386	4.101	4.817	5.532	.....	.....	.....	.....	.....	.....
0.148	9	2.532	2.729	2.927	3.322	3.717	4.508	5.298	6.088	6.879	7.669	8.064	8.262	8.459	9.250
0.165	8	.....	.....	.....	.....	4.114	4.995	5.877	6.758	7.639	8.520	8.960	9.181	9.401	10.282
0.180	7	.....	.....	.....	.....	4.460	5.421	6.382	7.343	8.304	9.266	9.746	9.987	10.227	11.188

2. *Section 10.*—Change to read as follows by the addition of the italicized words:

"If the results of the *physical* tests *of only one tube from any lot* do not conform to the requirements specified in Sections 3, 4, or 5, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified."

3. *Section 12.*—Insert a new Section 12 limiting the weights of tubes to certain percentages over and under the weights specified in Table I as follows:

"(*a*) The weight of tubes under 3½ in. in outside diameter shall vary not more than 5 per cent above or below that specified in table I.

"(*b*) Tubes 3½ in. and over in outside diameter may vary 2½ per cent below and 7½ per cent above that specified."

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[1] 1918 Book of A.S.T.M. Standards.

Renumber the present Section 12 to Section 13, at the same time revising Paragraph (*b*) to read as follows by the addition of the italicized words and the omission of the words in brackets:

> "The thickness at any point shall not vary more than [one gage] *two gages* above or one gage below that specified. In the case of boiler tubes which are expanded and swaged, the thickness of the expanded end may be 1½ gages lighter and of the swaged end three gages heavier than the thickness specified."

4. Revise Table I on Standard Weights to conform to Table I given in this appendix.

STANDARD SPECIFICATIONS FOR ENGINE-BOLT IRON (A 40 – 18).[1]

Section 3 (*a*).—Change the present requirements as to tensile properties: namely,

Tensile strength, lb. per sq. in. (See Section 4.)	50 000 – 54 000
Yield point, min., lb. per sq. in.	0.6 tens. str.
Elongation in 8 in., min., per cent	25
Reduction of area, " "	40

to conform to the following:

	$1\frac{1}{4}$ SQ. IN. AND UNDER IN SECTIONAL AREA.	OVER $1\frac{1}{4}$ SQ. IN. TO 4 SQ. IN., INCLUSIVE, IN SECTIONAL AREA.	OVER 4 SQ. IN. IN SECTIONAL AREA.
Tensile strength, lb. per sq. in.	49 000 – 53 000	47 000 – 53 000	47 000 – 53 000
Yield point, min., lb. per sq. in.	0.6 tens. str.	0.55 tens. str.	0.5 tens. str.
Elongation in 8 in., min. per cent	25	25	25
Reduction of area, min. per cent	40	40	40

TENTATIVE SPECIFICATION FOR EXTRA REFINED WROUGHT-IRON BARS (A 79 – 19 T).[2]

Section 4 (*a*).—Change the present requirement for yield point: namely,

"Yield point, min., lb. per sq. in. .... 0.6 tens. str."

to conform to the following.

	$1\frac{1}{4}$ SQ. IN. AND UNDER IN SECTIONAL AREA.	OVER $1\frac{1}{4}$ SQ. IN. TO 4 SQ. IN., INCLUSIVE, IN SECTIONAL AREA.	OVER 4 SQ. IN. IN SECTIONAL AREA.
Yield point, min., lb. per sq. in.	0.6 tens. str.	0.55 tens. str.	0.5 tens. str.

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[1] 1918 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 522 (1920).

REPORT OF COMMITTEE A-3
ON
CAST IRON.

Two matters of importance have been taken up by your committee during the past year, one of which is a revision of the existing Standard Specifications for Cast-Iron Car Wheels. The sub-committee on this subject has given the matter extended study since the close of the war and has submitted its report to the general committee in special session. Being approved, there is hereby[1] presented to the Society the newly revised Specifications for Cast-Iron Car Wheels with the request that they be accepted as tentative.

The other work that has been undertaken is in connection with the general sentiment among engineers and foundrymen that the misleading appellation of a very useful form of cast iron—so-called "semi-steel"—be done away with, and the material itself be standardized so far as this may be accomplished by definite specifications for the physical properties usually designated. The addition of steel scrap to foundry mixtures dates back to the Civil War, and through the reduction of the total carbon thereby the strength of the resulting castings is enhanced considerably. The improvement is, however, one of degree and depends upon the percentage of low-carbon steel scrap added and equally as much upon the metallurgical skill of the foundryman. Necessarily, the tendency to charge high prices for the product exists, whether much or little steel has been used, whether the melting process has been so conducted that a marked reduction in the total carbon has really been accomplished, and whether the product is free from blow-holes and excessive internal shrinkages.

It was recognized that two things must be done to accomplish this much desired reform: first, find a suitable designation for comparatively low-total-carbon gray-iron castings; and second, draw the line somewhere which will distinguish them from the ordinary classes of specification product. A name has been tentatively adopted for the want of something better, in "high-test" cast iron, and your committee is very earnest in inviting the members of the Society who have experience with this class of castings to improve upon the designation here given. Parenthetically it may be stated that when the matter was broached in committee meeting the sentiment against the word "semi-steel" as even a trade designation was unanimous. Particular prominence is given the matter in this report to point out the wisdom of opposing the introduction of a misleading designation for an engineering material when it comes up, rather than wait until the term has gained extensive usage in current literature.

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[1] See p. 481.—Ed.

Again, it has been decided that the most satisfactory way to draw the dividing line between this "high-test" cast iron and the ordinary specification product would be to adopt a new set of specifications in which the physical requirements were such that they can only be reached by the use of proper materials and expert knowledge. The foundryman who could meet such specifications would then be entitled to the natural reward for his superior ability. The specifications for this "high-test" cast iron are now under consideration and, it is hoped, will be worked out during the coming year.

Your committee has been forced to mark time on several other developments, such as specifications for molding sand, foundry scrap, patterns, etc., for in all of these progress is dependent upon cooperation with committees of other societies. Progress has also been made with the questions of Nomenclature and Methods of Testing, and doubtless "Recommended Practice" in foundry metallurgy and shop procedure will eventually form part of the activity of your committee.

This report has been submitted to letter ballot of the committee, which consists of 50 members, of whom 30 have voted affirmatively, none negatively, and 20 have refrained from voting.

Respectfully submitted on behalf of the committee,

RICHARD MOLDENKE,
Chairman.

GEORGE C. DAVIES,
Secretary.

ADDENDUM TO REPORT OF COMMITTEE A-3.

At a meeting of Committee A-3 held on Thursday, June 23, 1921, prior to the presentation of its annual report to the Society, it was recommended that the following revisions in the proposed Tentative Specifications for Cast-Iron Car Wheels (A 46 – 21 T) be submitted to the Society in connection with the printed report of the committee.

Insert a section on chemical requirements to read as follows:

"(*a*) The wheels shall conform to the following requirements as to chemical composition:

Combined carbon		0.50 – 0.85	per cent
Silicon		0.45 – 0.75	"
Manganese		0.50 – 0.75	"
Phosphorus	not over	0.40	"
Sulfur	" "	0.18	"

"(*b*) The minimum percentage of manganese shall be not less than three times the sulfur content.

"(*c*) It is desired that the phosphorus content shall not exceed 0.30 per cent.

"3. Drillings for chemical analysis shall be taken from drill hole bored entirely through the back double plate of the wheel between core legs."

Respectfully submitted,
RICHARD MOLDENKE,
Chairman.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Cast-Iron Car Wheels as subsequently amended, as given in the addendum to this report, were accepted for publication as new Tentative Specifications for Cast-Iron Car Wheels and appear on pages 481–485. The standard specifications were accordingly withdrawn.

REPORT OF COMMITTEE A-4
ON
HEAT TREATMENT OF IRON AND STEEL.

At a meeting on September 16, 1920, your committee reorganized with an enlarged membership and appointed the following sub-committees:

Sub-Committee I on Heat Treatment of Rolled and Forged Carbon Steel.

Sub-Committee II on Heat Treatment of Steel Castings.

Sub-Committee III on Heat Treatment of Alloy Steels.

Sub-Committee IV on Case Hardening and Heat Treatment of Case-Hardened Objects.

Sub-Committee V on Heat Treatment of Wrought Iron.

Sub-Committee II has been engaged in the revision of Recommended Practices for Annealing Carbon-Steel Castings (A 36 – 14), but was unable to finish the task in time for presentation this year.

Sub-Committee V has not yet organized but has under consideration two subjects for investigation. The first is the heat treatment of wrought iron in special cases, such as chain and other articles, where the metal has been brought to a high temperature for welding. The second subject considered is the red shortness of wrought iron when subjected to mechanical work at temperatures around 1500° F.

Sub-Committee I has reviewed the existing Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects (A 35 – 11)[1] and recommends the following changes:

Section 2.—Change the next to the last sentence in this section from its present form: namely,

> "An exposure of one hour should be long enough for pieces 12 in. thick"

to read as follows:

> "An exposure of forty-five minutes should be long enough for each inch of thickness."

Omit the last sentence of the section.

This change is recommended inasmuch as practice usually involves maintaining the piece at the temperature designated for a much longer time than that formerly given.

Section 13.—In the second sentence of this section omit the following statement:

> ". . . in the case of objects with not over 0.03 per cent carbon and not too thin, by a temporary immersion in oil or even water, followed by a return to the furnace."

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[1] **1918 Book of A.S.T.M. Standards.**

This procedure does not appear to be properly a part of an annealing operation, and the committee believes this sentence should be modified as indicated.

In addition this sub-committee has recommended certain changes in existing standard specifications of Committee A-1 in sections referring to heat treatment. These changes have been brought to the attention of Committee A-1.

Sub-Committee III.—The scope of this sub-committee is limited to those steels containing individually or in combination:

Manganese	not less than	1.00 per cent
Silicon	" " "	0.75 "
Nickel	" " "	0.50 "
Chromium	" " "	0.30 "
Vanadium	" " "	0.10 "
Molybdenum	" " "	0.10 "

It is proposed to omit from consideration alloy steels not commercially used.

The immediate activity of this sub-committee is confined to the S.A.E. analyses listed below:

2315[1]	3120	3220	3320[1]	3415	52100	6120	8100 (Mo. Series)
2320[1]	3125	3230	3330[1]	3435		6125	
2330[1]	3130	3240	3340[1]	3450		6135	
2335[1]	3135	3250				6140	
2340[1]	3140					6145	
2345[1]						6150	
						6195	

The sub-committee proposes for its use, the following order and abbreviations of:

1. *Chemical Elements.*—

	ABBREVIATION.		ABBREVIATION.
Carbon	C.	Molybdenum	Mo.
Manganese	Mn.	Tungsten	W.
Phosphorus	P.	Copper	Cu.
Sulfur	S.	Cobalt	Co.
Silicon	Si.	Uranium	U.
Nickel	Ni.	Zirconium	Zr.
Chromium	Cr.	Titanium	Ti.
Vanadium	V.		

2. *Physical Properties.*—

	ABBREVIATION.
Elastic limit	E. L.
Tensile strength	T. S.
Elongation	Elon.
Reduction of area	Red.
Brinell	Br.
Scleroscope	Scl.

Bend, Size of test piece, angle of bend, size of pin.

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[1] The lower limit for nickel is placed at 3.00 per cent instead of 3.25 per cent.

The following heat treatment terms as defined will be adopted by this sub-committee:

1. *Normalizing.*—Heating above the upper critical temperature followed by cooling in air.
2. *Annealing.*—Heating above the upper critical temperature followed by slow cooling as desired.
3. *Quenching.*—Heating to a temperature above the upper critical temperature, followed by rapid cooling in some medium.
4. *Drawing.*—Heating to some temperature below the lower limit of the Ac range, followed by cooling as desired.

For the uniform presentation of data, this sub-committee will use the S.A.E. graphs.

The members of this sub-committee are now checking the treatments and physical results of 1½-in. rounds and squares as determined by S.A.E. and have as their objective, commercially obtainable results to be expected from 1-in. rounds or squares.

The sub-committee recommends extended accumulation of data covering heat treatments and physical results commercially obtainable for larger sections, plotted for convenient comparison with the standard graphs mentioned above.

In addition to the above this sub-committee believes that it can and should be of service to the Society through study and advice in connection with such alloy steel heat-treatment problems as may be submitted to it by other committees.

Finally the sub-committee submits the following as covering information which may prove helpful:

The advantage of alloy steels over simple steels lies in the fact that they are more sensitive to heat treatment and capable of giving higher properties when properly handled. The increased sensitiveness to treatment unfortunately is accompanied by a proportionate sensitiveness to failure during treatment, which requires greater care in all treatment operations and necessitates the elimination of abrupt changes in section. The following suggestions are made to overcome this difficulty:

1. Heavy solid alloy forgings should not be allowed to cool but should immediately be put in an annealing furnace and normalized.

2. High Nickel-Chrome, Chrome-Vanadium, or any other alloy steel bars and small forgings liable to shattering should be cooled slowly after rolling by burying in warm ashes or lime to retard the cooling. High carbon, even with a moderate alloy content, increases the risk of cracking.

3. A thorough annealing or normalizing above the upper critical point after rolling or forging eliminates much danger of later troubles due to cracks and strains and leaves the metal in a better condition to secure the maximum effect of the quench.

4. Annealing only does not develop high physical properties but leaves the metal soft, uniform and ductile. To break up forging and rolling structures which are detrimental the piece should be double annealed, first at 100 to 200° F. above the critical range followed by an anneal slightly above the critical range.

5. In heating for either annealing or quenching, the piece should be slowly and uniformly brought to temperature, the rate depending on grade and section, especially through the brittle range (up to 800° F).

6. For quenching, the piece should be uniformly heated above the critical range and introduced into the quenching medium with no delay after leaving the furnace.

7. Quenching is the most drastic treatment operation, and therefore the most dangerous. Alloys or sections subject to water cracks should be quenched in circulating oil.

8. In drawing after quenching the piece must be slowly and uniformly heated to the proper temperature but may be cooled slowly or rapidly as desired.

This report has been submitted to letter ballot of the committee which consists of 21 members, of whom 16 have voted affirmatively, none negatively, and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. M. BOYLSTON,
Chairman.

J. H. HALL,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the existing Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon-Steel Objects referred to in this report were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The recommended practice as thus revised appears in the 1921 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE A-5

ON

CORROSION OF IRON AND STEEL.

The report of Committee A-5 for this year consists of the reports of Sub-Committee II on Preservative Metallic Coatings for Metals, Sub-Committee III on Inspection of the Corrosion Tests at Fort Sheridan, Ill., Pittsburgh, Pa., and Annapolis, Md., and Sub-Committee V on Total Immersion Tests.

The difficulties of obtaining funds for Sub-Committee II have increased rather than diminished since last year and for the present it will be impossible to conduct an exposure test on zinc-coated sheets. The general methods of testing these materials are being studied along the lines mentioned in previous reports.

It is also hoped, through cooperation with Committee A-1, to establish allowable tolerances for the coating on galvanized sheets.

The report of Sub-Committee III on Inspection of the Corrosion Tests at Fort Sheridan, Pittsburgh, and Annapolis constitutes the major part of this report.

Further failures at Fort Sheridan have been recorded; the No. 22 gage Bessemer and Basic Open-Hearth Sheets, which failed first at Pittsburgh, have failed in this series. The subsequent failures, which will now occur at an increasing rate, will be watched with keen interest to determine if the general trend of failures continues to follow the results at Pittsburgh.

The Pittsburgh test is nearing completion. Out of the light gage sheets no failures were recorded for the copper-bearing sheets at 16 months while 35 per cent of the non-copper bearing sheets had failed, at 28 months 4.1 per cent of the copper-bearing sheets had failed for 91.6 per cent failure of the non-copper sheets. At the end, now, of 52 months, 63 per cent of the copper sheets has failed and 97 per cent of the non-copper sheets. In the heavier gage no failure of the copper sheets is recorded and 42.9 per cent failure of non-copper sheets is recorded. It is, therefore, evident that this particular test at Pittsburgh has told its story.

No failures have occurred at Annapolis.

The total immersion test has developed interesting results; all of the specimens immersed in the acid mine water of the Pittsburgh section have failed and the presence or absence of copper appears to have little connection with the failures. It will require a careful study of the results to determine if the composition has influenced the results. A complete tabulation of the results are contained in the report so that they can be readily analyzed by all interested in the test. No failures have occurred in the specimens immersed in either the Severn water at Annapolis or the City water of Washington at the Bureau of Standards.

This report has been submitted to letter ballot of the committee, which consists of 43 members, of whom 30 have voted affirmatively, 1 negatively, and 12 have refrained from voting.

Respectfully submitted on behalf of the committee,

S. S. VOORHEES,
Chairman.

J. A. AUPPERLE,
Secretary.

REPORT OF SUB-COMMITTEE II ON PRESERVATIVE METALLIC COATINGS FOR METALS.

Sub-Committee II on Preservative Metallic Coatings for Metals has held no formal meetings during the past year.

In the last report of the sub-committee, mention was made of a proposed series of exposure tests of coated sheets which had been drawn up by the sub-committee at the suggestion of Committee A-5. At the last annual meeting of the committee, Sub-Committee II was advised by the main committee that on account of the difficulty of raising sufficient funds for the investigation, and of the impossibility of securing permanent locations for the exposure panels for the long periods such tests would require, the proposed tests should be abandoned.

A small sub-committee under the chairmanship of Mr. D. M. Buck was appointed for the purpose of drawing up suitable specifications for galvanized sheets and other products. No report on this subject can be made at this time.

Respectfully submitted on behalf of the sub-committee,

G. K. Burgess,
Chairman.

REPORT OF SUB-COMMITTEE III ON INSPECTION OF THE FORT SHERIDAN, PITTSBURGH AND ANNAPOLIS TESTS.

Sub-Committee III on Inspection has held three meetings during the past year.

First Meeting.

The first meeting was held at Fort Sheridan, Ill., on October 11, 1920, with Messrs. Aupperle, Buck, Cooper, Fleming, Smith and Wheaton present; Messrs. Gibboney, McDonnell and the representative of the Bureau of Steam Engineering of the U. S. Navy Department being absent.

The Fort Sheridan sheets were inspected on October 11, 1920, followed by the inspection of the Pittsburgh sheets on October 12, 1920, and the Annapolis sheets on October 13, 1920. Mr. McDonnell joined the sub-committee at Pittsburgh, and the representative of the Bureau of Steam Engineering of the U. S. Navy Department joined the sub-committee at Annapolis. Members filing data sheets for these inspections are as follows:

Fort Sheridan.—Messrs. Aupperle, Buck, Cooper, Fleming, Smith and Wheaton.

Pittsburgh.—Messrs. Aupperle, Buck, Cooper, Fleming, McDonnell, Smith and Wheaton.

Annapolis.—Messrs. Aupperle, Buck, Cooper, Fleming, McAdam, McDonnell, Smith and Wheaton.

The results of these inspections are shown in composite form as Tables I, II and III, Plates I, II and III.

The following photographs of the Fort Sheridan sheets, showing failures taking place at this location, were made on October 11, 1920, representing an exposure period of 42 months:

Figs. 1 and 2 represent the condition of sheets O 17 and 18, 21 and 22 (No. 22 Gage Low-Copper Open-hearth Steel, Series A). Sheets failed due to holes in lower ends.

Fig. 3 represents the condition of sheet Y 4 (No. 22 Gage Low-Copper Wrought Iron, Series B), manufactured by the Youngstown Sheet and Tube Company. This sheet failed due to holes in lower ends.

The following photographs of the Pittsburgh sheets, showing failures taking place at this location, were made on October 12, representing an exposure period of 46 months.

Fig. 5 shows the general view for the Pittsburgh sheets as appearing on the rack at this inspection.

Figs. 4 and 6 represent the condition of sheets B 21 and 22, 23 and 34 (No. 22 Gage Open-hearth Steel, Series A), sheets B 21 and 23 having failed due to holes in lower ends. Sheets B 22 and 34 have not failed at this inspection.

Fig. 7 represents the condition of sheets C 33 and 34 (No. 22 Gage Copper-Bearing Pure Iron, Series A), sheet C 33 having failed due to holes in lower end. Sheet C 34 was reported as failed at the May 11, 1920, inspection.

Figs. 8 and 9 represent the condition of sheets M 39 and 40, 41 and 42 (No. 22 Gage Open-hearth Steel, Series B), manufactured by the Alan Wood Iron and Steel Co. Sheets M 39 and 41 have failed due to holes in lower ends. Sheet M 42 was reported as failed at the May 11, 1920, inspection. Sheet M 40 has not failed.

Figs. 10 to 14, inclusive, represent the condition of sheets T 29 and 30, 31 and 32, 33 and 34, 39 and 40, and 41 and 42 (No. 22 Gage Copper-Bearing Steel, Series B), manufactured by the Newport Rolling Mill Co. Sheets T 29, 30, 31, 34, 40, 41 and 42 have failed due to holes in lower ends. Sheet T 39 was reported as failed at the November 5, 1919, inspection. Sheets T 32 and 33 were reported as failed at the May 11, 1920, inspection.

Figs. 15 to 19, inclusive, represent the condition of sheets U 31 and 32, 33 and 34, 35 and 36, 38 and 39, 41 and 42 (No. 22 Gage Copper-Bearing Pure Iron, Series B), manufactured by the Allegheny Steel Co. Sheets U 31, 33, 34, 35, 38 and 42 failed due to holes in lower ends. Sheet U 41 was reported as failed at the November 5, 1919, inspection. Sheets U 32, 36 and 39 have not failed.

Figs. 20 to 24, inclusive, represent the condition of sheets V 29 and 30, 33 and 34, 35 and 36, 38 and 39, 40 and 41 (No. 22 Gage Copper-Bearing Pure Iron, Series B), manufactured by the Whitaker-Glessner Co. Sheets V 30, 33, 34, 35, 38, 40 and 41 have failed due to holes in lower ends. Sheets V 29 and 39 were reported as failed at the November 5, 1919, inspection. Sheet V 36 was reported as failed at the May 11, 1920, inspection.

Sheet OO 27 (No. 16 Gage Low-Copper Open-hearth Steel, Series A) is reported as failed, due to holes in lower end. No photographic record was made of this sheet at this inspection, due to inability because of location, to place the photographic tower between the sheets and the wall of an adjacent building.

Figs. 25 to 28, inclusive, represent the condition of sheets SS 33 and 34, 35 and 36, 37 and 38, 41 and 42 (No. 16 Gage Low-Copper

Pure Iron, Series B), manufactured by the American Rolling Mill Co. Sheets SS 34, 36, 37, 38, 41 and 42 have failed due to holes and ragged edges in lower ends. Sheets SS 33 and 35 were reported as failed at the May 11, 1920. inspection.

Fig. 29 represents the condition of sheets XX 35 and 36 (No. 16 Gage Low-Copper Pure Iron, Series B), manufactured by the Inland Steel Co. Sheet XX 36 failed due to hole and ragged edges at lower end. Sheet XX 35 has not failed.

The rate of corrosion for the test sheets at Annapolis continues comparatively slow, no failures having occurred at this location after an exposure period of 48 months.

All sheets that have failed prior to October 13, 1920, have been reported, and with few exceptions (Row No. 1, Pittsburgh tests) have been photographed for permanent record.

SECOND MEETING.

The second meeting was held at Fort Sheridan, Ill., on April 4, 1921, with Messrs. Aupperle, Buck, Fleming, McDonnell, Llewelyn (representing the Bureau of Steam Engineering of the U. S. Navy Department), Smith, and Voorhees (*ex-officio*) present; Messrs. Cooper, Gibboney and Wheaton being absent.

The Fort Sheridan sheets were inspected on April 4, 1921, followed by the inspection of the Pittsburgh sheets on April 5, 1921. Mr. Cooper joined the sub-committee at Pittsburgh and Mr. Caldwell represented the Bureau of Steam Engineering of the U. S. Navy Department at this inspection.

Members filing data sheets for these inspections are as follows:

Fort Sheridan.—Messrs. Aupperle, Buck, Fleming, McDonnell and Smith.

Pittsburgh.—Messrs. Aupperle, Buck, Cooper, Fleming, McDonnell and Smith.

The results of these inspections are shown in composite form as Tables IV and V, Plates IV and V.

The following photographs of the Fort Sheridan sheets showing failures at this location were made on April 4, 1921, representing an exposure period of 48 months.

Fig. 30 shows the general view of the Fort Sheridan sheets as appearing on the rack on April 4, 1921.

Figs. 31 and 32 represent the condition of sheets A 19 and 20, 29 and 30 (No. 22 Gage Bessemer Steel, Series A). Sheets 19, 29 and 30 have failed due to one or more holes in lower ends. Sheet A 20 has not failed.

Fig. 33 represents an enlarged view of a blister near the bottom of sheet A 29 (No. 22 Gage Bessemer Steel, Series A), this blister being responsible for failure. The coarse texture illustrated in this photograph is characteristic for sheets showing failures at this location.

Fig 34 represents the condition of sheets X 25 and 26 (No. 22 Gage Low-Copper Pure Iron, Series B), manufactured by the Inland Steel Co. Sheet X 25 has failed due to hole in lower end.

Fig. 35 represents the condition of sheets Z 4 and 5 (No. 22 Gage Bessemer Steel, Varying Copper Content, Series B), manufactured by the Youngstown Sheet and Tube Co., having failed due to one or more holes at lower ends.

The following photographs of the Pittsburgh sheets showing failures taking place at this location were made on April 5, representing an exposure period of 52 months.

Fig. 37 shows the general view of the Pittsburgh sheets as appearing on the rack at this inspection.

Figs. 36, 38 and 39 represent the condition of sheets B 21 and 22, 34 and 35, 38 and 39 (No. 22 Gage Open-hearth Steel, Series A). Sheets B 22, 34 and 39 have failed due to holes in lower ends. Sheet B 21 was reported as failed at the October 12, 1920, inspection. Sheet B 35 was reported as failed at the November 5, 1919, inspection. Sheet B 38 was reported as failed at the April 1, 1919, inspection.

Fig. 40 represents the condition of sheets C 11 and 12 (No. 22 Gage Copper-Bearing Pure Iron, Series A). Sheet C 12 has failed due to holes in lower end. Sheet C 11 was reported as failed at the November 5, 1919, inspection.

Figs. 41 to 46, inclusive, represent the condition of sheets H 38 and 40, 41 and 42, 43 and 45, 47 and 49, 50 and 53, 54 and 55 (No. 22 Gage Copper-Bearing Basic Open-hearth Steel, Series A). Sheets 38, 40, 42, 45, 49, 50, 53, 54 and 55 have failed due to holes in lower ends. Sheets H 41, 43 and 47 have not failed at this inspection.

Figs. 47 to 51, inclusive, represent the condition of sheets M 29 and 30, 33 and 34, 35 and 36, 37 and 38, 39 and 40 (No. 22 Gage Open-hearth Steel, Series B), manufactured by the Alan Wood Iron and Steel Co. Sheets 29, 30, 33, 34, 35, 37, 38 and 40 have failed due to holes in lower ends. Sheet M 36 was reported as failed at the May 11, 1920, inspection. Sheet M 39 was reported as failed at the October 12, 1920, inspection.

Figs. 52 to 54, inclusive, represent the condition of sheets U 31 and 32, 36 and 37, 39 and 40 (No. 22 Gage Copper-Bearing Pure Iron, Series B), manufactured by the Allegheny Steel Co. Sheets U 32, 36, 37 and 39 have failed, due to holes in lower end. Sheet U 31 was reported as failed at the October 12, 1920, inspection. Sheet U 40 was reported as failed at the May 11, 1920, inspection.

Fig. 55 represents the condition of Sheets V 31 and 32 (No. 22 Gage Copper-Bearing Pure Iron, Series B), manufactured by the Whitaker-Glessner Co., having failed due to one or more holes in lower ends.

Fig. 56 represents the condition of sheets Z 112 and 113 (No. 22 Gage Bessemer Steel, Varying Copper Content, Series B), manufactured by Youngstown Sheet and Tube Co. Sheet Z 113 has failed due to hole in lower end. Sheet Z 112 has not failed.

Fig. 57 represents the condition of sheets Z 714 and 715 (No. 16 Gage Open-hearth Steel, Varying Copper Content, Series B), manufactured by the Youngstown Sheet and Tube Co. Sheet Z 715 has failed due to one or more holes in the lower end. Sheet Z 714 has not failed.

Fig. 58 represents the condition of sheets DD 25 and 26 (No. 16 Gage Low-Copper Pure Iron, Series A), having failed due to holes and ragged edges at the lower ends.

Figs. 59 to 61, inclusive, represent the condition of sheets OO 25 and 26, 27 and 28, 33 and 34 (No. 16 Gage Low-Copper Open-hearth Steel, Series A). Sheets OO 25, 26, 28 and 33 have failed, due to holes and ragged edges at the lower ends. Sheet OO 27 was reported as failed at the October 12, 1920, inspection. Sheet OO 34 has not failed.

Figs. 62 to 65, inclusive, represent the condition of sheets XX 33 and 34, 35 and 36, 38 and 39, 40 and 41 (No. 16 Gage Low-Copper Pure Iron, Series B), manufactured by the Inland Steel Co. Sheets XX 33, 34, 35, 38, 39 and 40 have failed due to holes and ragged edges at the lower ends. Sheet XX 36 was reported as failed at the October 12, 1920, inspection. Sheet XX 41 was reported as failed at the May 11, 1921, inspection.

Figs. 66 and 67 represent the condition of sheets YY 7 and 8, and 9 (No. 16 Gage Low-Copper Wrought Iron, Series B), manufactured by the Youngstown Sheet and Tube Co. Sheets YY 7 and 9 have failed due to one or more holes in the lower ends. Sheet YY 8 has not failed.

Following the same general plan of presenting the average results of the various inspectors as appearing in previous reports of the sub-

Date of Inspection Oct. 11, 1920.

ROW No. 1

DESIGNATION		CONDITION OF RUST																										
		Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	11	VC	VC	VC	VC				C	C	L	L	M	L				M	D	L	L	L	L				L	T
	12	VC	VC	VC	VC				C	C	L	L	M	L				M	D	L	L	L	L				L	T
	13	VC	VC	VC	VC				C	C	L	L	M	L				M	D	L	L	L	L				L	T
BB	4	M	S	C	S				M	M	D	M	D	D				D	D	T	T	TL	T				T	T
	5	M	S	C	S				M	M	D	M	D	D				D	D	T	T	TL	T				T	T
	6	M	S	C	S				M	M	D	M	D	D				D	D	T	T	TL	T				T	T
CC	8	M	C	VC	C				C	C	M	L	L	L				M	M	T	L	TL	L				T	T
	9	M	C	VC	C				C	C	M	L	L	L				M	M	T	L	TL	L				T	T
	10	M	C	VC	C				C	C	M	L	L	L				M	M	T	L	TL	L				T	T
DD	18	M	C	C	C				C	C	M	L	L	L				M	M	T	L	TL	L				T	T
	19	M	C	C	C				C	C	M	L	L	L				M	M	T	L	TL	L				T	T
	20	M	C	C	C				C	C	M	L	L	L				M	M	T	L	TL	L				T	T
EE*	7	VS	M	M	M				S	M	D	M	D	D				D	D	T	T	TL	T				T	T
	8	VS	M	M	M				S	M	D	M	D	D				D	D	T	T	TL	T				T	T
	9	VS	M	M	M				S	M	D	M	D	D				D	D	T	T	TL	T				T	T
HH	10	S	S	M	S				S	M	D	D	D	D				D	D	T	T	TL	T				T	T
	11	S	S	M	S				S	M	D	D	D	D				D	D	T	T	TL	T				T	T
	12	S	S	M	S				S	M	D	D	D	D				D	D	T	T	TL	T				T	T
II	10	S	VS	M	S				S	S	D	D	D	D				D	D	T	T	TL	T				T	T
	11	S	VS	M	S				S	S	D	D	D	D				D	D	T	T	TL	T				T	T
	12	S	VS		S				S	S	D	D	D	D				D	D	T	T	TL	T				T	T
KK	4	S	VS	M	S				S	M	D	D	D	D				D	D	T	T	TL	T				T	T
	5	S	VS	M	S				S	M	D	D	D	D				D	D	T	T	TL	T				T	T
	18	S	VS	M	S				S	M	D	D	D	D				D	D	T	T	TL	T				T	T
MM*	15	M	M	M	M				M	C	D	M	D	D				D	M	T	T	TL	T				T	T
	16	M	M	M	M				M	C	D	M	D	D				D	M	T	T	TL	T				T	T
	17	M	M	M	M				M	C	D	M	D	D				D	M	T	T	TL	T				T	T
SS	15	C	VC	C	VC				C	VC	L	L	L	L				L	D	L	L	TL	L				L	T
	16	C	VC	C	VC				C	VC	L	L	L	L				L	D	L	L	TL	L				L	T
	17	C	VC	C	VC				C	VC	L	L	L	L				L	D	L	L	TL	L				L	T
TT	15	S	S	M	S				S	M	D	D	M	D				M	D	T	T	TL	T				T	T
	16	S	S	M	S				S	M	D	D	M	D				M	D	T	T	TL	T				T	T
	17	S	S	M	S				S	M	D	D	M	D				M	D	T	T	TL	T				T	T
UU	15	S	S	C	M				S	C	M	D	M	D				M	D	T	T	TL	T				T	T
	16	S	S	C	M				S	C	M	D	M	D				M	D	T	T	TL	T				T	T
	17	S	S	C	M				S	C	M	D	M	D				M	D	T	T	TL	T				T	T
VV	20	S	M	C	M				S	C	M	D	D	D				M	D	T	T	TL	T				T	T
	21	S	M	C	M				S	C	M	D	D	D				M	D	T	T	TL	T				T	T
	22	S	M	C	M				S	C	M	D	D	D				M	D	T	T	TL	T				T	T
XX	15	C	C	C	C				C	VC	M	M	M	M				M	D	L	L	L	L				L	T
	16	C	C	C	C				C	VC	M	M	M	M				M	D	L	L	L	L				L	T
	17	C	C	C	C				C	VC	M	M	M	M				M	D	L	L	L	L				L	T
OO	13	C	C	VC	C				M	VC	M	M	M	M				M	D	L	L	L	L				L	T
	14	C	C	VC	C				M	VC	M	M	M	M				M	D	L	L	L	L				L	T
	15	C	C	VC	C				M	VC	M	M	M	M				M	D	L	L	L	L				L	T
CCC	13	C	C	C	C				M	VC	M	M	M	M				M	D	T	L	L	L				L	T
	14	C	C	C	C				M	VC	M	M	M	M				M	D	T	L	L	L				L	T
	15	C	C	C	C				M	VC	M	M	M	M				M	D	T	L	L	L				L	T

* Open Annealed.

ROW No. 2

DESIGNATION		CONDITION OF RUST																										
		Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
A	16				C					C				L					D				L					T
	17				C					C				L					D				L					T
	18				C					C				L					D				L					T
B	9	S	S	M	M				M	M	M	D	D	D				M	D	T	T	L	T				L	T
	10	S	S	M	M				M	M	M	D	D	D				M	D	T	T	L	T				L	T
	11	S	S	M	M				M	M	M	D	D	D				M	D	T	T	L	T				L	T
C	6	M	M	M	C				M	C	M	L	L	L				M	D	T	L	TL	L				L	T
	7	M	M	M	C				M	C	M	L	L	L				M	D	T	L	TL	L				L	T
	8	M	M	M	C				M	C	M	L	L	L				M	D	T	L	TL	L				L	T
D	18	C	C	C	VC				C	VC	M	L	L	L				L	D	L	L	L	L				L	T
	19	C	C	C	VC				C	VC	M	L	L	L				L	D	L	L	L	L				L	T
	22	C	C	C	VC				C	VC	M	L	L	L				L	D	L	L	L	L				L	T
E	13	M	S	M	M				M	C	M	D	D	D				M	D	T	T	T	T				L	T
	14	M	S	M	M				M	C	M	D	D	D				M	D	T	T	T	T				L	T
	15	M	S	M	M				M	C	M	D	D	D				M	D	T	T	T	T				L	T
H	19	S	S	S	M				M	C	D	D	D	D				M	D	T	T	T	T				T	T
	20	S	S	S	M				M	C	D	D	D	D				M	D	T	T	T	T				T	T
	22	S	S	S	M				M	C	D	D	D	D				M	D	T	T	T	T				T	T
I	19	VS	VS	VS	S				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	20	VS	VS	VS	S				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	21	VS	VS	VS	S				S	M	D	D	D	D				M	D	T	T	T	T				T	T
K	17	M	S	M	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	18	M	S	M	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	19	M	S	M	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
M	15	M	M	M	M				S	C	D	M	D	D				M	D	T	T	T	T				L	T
	16	M	M	M	M				S	C	D	M	D	D				M	D	T	T	T	T				L	T
	17	M	M	M	M				S	C	D	M	D	D				M	D	T	T	T	T				L	T
R	15	VC	VC	VC	VC				C	VC	M	L	L	L				L	M	L	L	L	L				L	T
	16	VC	VC	VC	VC				C	VC	M	L	L	L				L	M	L	L	L	L				L	T
	17	VC	VC	VC	VC				C	VC	M	L	L	L				L	M	L	L	L	L				L	T
T	15	M	S	M	S				M	C	D	D	M	D				M	D	T	T	TL	T				L	T
	16	M	S	M	S				M	C	D	D	M	D				M	D	T	T	TL	T				L	T
	17	M	S	M	S				M	C	D	D	M	D				M	D	T	T	TL	T				L	T
U	15	C	M	C	M				M	C	D	D	M	D				M	D	T	T	TL	T				L	T
	16	C	M	C	M				M	C	D	D	M	D				M	D	T	T	TL	T				L	T
	17	C	M	C	M				M	C	D	D	M	D				M	D	T	T	TL	T				L	T
V	15	M	M	C	M				M	C	D	D	M	M				M	D	T	T	TL	T				L	T
	16	M	M	C	M				M	C	D	D	M	M				M	D	T	T	TL	T				L	T
	17	M	M	C	M				M	C	D	D	M	M				M	D	T	T	TL	T				L	T
X	15	C	C	VC	C				C	VC	M	L	L	L				L	D	L	L	L	L				L	T
	16	C	C	VC	C				C	VC	M	L	L	L				L	D	L	L	L	L				L	T
	17	C	C	VC	C				C	VC	M	L	L	L				L	D	L	L	L	L				L	T
O	13				VC					VC				L					D				L					T
	14				VC					VC				L					D				L					T
	15				VC					VC				L					D				L					T
Z	4	C	C	C	M				C	C	M	L	M	M				L	D	L	L	L	L				L	T
	5	C	C	C	M				C	C	M	L	M	M				L	D	L	L	L	L				L	T
	109	VS	VS	VS	S				S	M	D	D	D	D				D	D	L	L	L	L				L	T

ROW No. 3

DESIGNATION		CONDITION OF RUST																										
		Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	14	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	15	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	16	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	17	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	18	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	19	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	20	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
AA*	42	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	43	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	44	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	45	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	46	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	47	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	48	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
	49	VC	VC	VC	VC				C	C	L	M	L	L				L	M	L	L	L	L				L	T
BB	7	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	15	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	16	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	17	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	18	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	19	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
BB*	29	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	30	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	31	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	32	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	46	VS	S	M	S				M	M	D	D	D	D				M	D	T	T	T	T				L	T
	47	VS	S	M	S				M	S	D	D	D	D				M	D	T	T	T	T				L	T
	48	VS	S	M	S				M	S	D	D	D	D				M	D	T	T	T	T				L	T
	49	VS	S	M	S				M	S	D	D	D	D				M	D	T	T	T	T				L	T
CC	11	C	C	VC	C				M	C	M	L	L	L				L	D	T	L	L	L				L	T
	12	C	C	VC	C				M	C	M	L	L	L				L	D	T	L	L	L				L	T
	13	C	C	VC	C				M	C	M	L	L	L				L	D	T	L	L	L				L	T
	14	C	C	VC	C				M	C	M	L	L	L				L	D	T	L	L	L				L	T
CC*	26	C	C	VC	C				C	C	M	L	L	L				L	D	T	L	L	L				L	T
	27	C	C	VC	C				C	C	M	L	L	L				L	D	T	L	L	L				L	T
	28	C	C	VC	C				C	C	M	L	L	L				L	D	T	L	L	L				L	T
	29	C	C	VC	C				C	C	M	L	L	L				L	D	T	L	L	L				L	T
	30	C	C	VC	C				C	C	M	L	L	L				L	D	T	L	L	L				L	T
DD	5	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
	6	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
	7	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
	21	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
	22	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
	23	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
	24	C	C	C	C				C	C	L	L	M	L				L	D	L	L	L	L				L	T
YY†	6	M	C	C	C				C	M	M	M	M	L				M	D	L	L	T	L				L	T
	4	M	C	C	C				C	M	M	M	M	L				M	D	L	L	T	L				L	T
	5	M	C	C	C				C	M	M	M	M	L				M	D	L	L	T	L				L	T
Y†	4	M		C	C				C	M	M		M	L				M	D	L		TL	L				L	T

* Sand Blasted.

† Exposed 6-13-17.

ROW No. 4

DESIGNATION		CONDITION OF RUST					
		Texture					
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam
DD*	39	C	C	C	VC		
	40	C	C	C	VC		
	44	C	C	C	VC		
	45	C	C	C	VC		
	46	C	C	C	VC		
	49	C	C	C	VC		
	51	C	C	C	VC		
	52	C	C	C	VC		
	53	C	C	C	VC		
EE†	10	S	M	S	S		
	11	S	M	S	S		
	12	S	M	S	S		
EE*†	25	S	M	S	S		
	26	S	M	S	S		
	27	S	M	S	S		
	28	S	M	S	S		
	29	S	M	S	S		
	30	S	M	S	S		
HH	13	S	S	S	M		
	14	S	S	S	M		
	15	S	S	S	M		
	16	S	S	S	M		
	17	S	S	S	M		
	18	S	S	S	M		
HH*	35	S	S	S	M		
	36	S	S	S	M		
	37	S	S	S	M		
	38	S	S	S	M		
	39	S	S	S	M		
	40	S	S	S	M		
	41	S	S	S	M		
	42	S	S	S	M		
II	13	S	VS	S	M		
	14	S	VS	S	M		
	15	S	VS	S	M		
	16	S	VS	S	M		
	17	S	VS	S	M		
	18	S	VS	S	M		
	19	S	VS	S	M		
II*	39	S	VS	S	M		
	40	S	VS	S	M		
	41	S	VS	S	M		
	42	S	VS	S	M		
	43	S	VS	S	M		
	44	S	VS	S	M		
	45	S	VS	S	M		
	46	S	VS	S	M		
	47	S	VS	S	M		

* Sand Blasted.

† Open Annealed.

— INSPECTION COMMITTEE —

CONDITION OF RUST.

Texture	Color	Adherence
VS — Very Smooth	L — Light	T — Tight
S — Smooth	M — Medium	L — Loose
M — Medium	D — Dark	
C — Coarse		
VC — Very Coarse		

J. H. Gibboney, Chairman — Norfolk & Western Ry. Co.
J. A. Aupperle — American Rolling Mill Co.
D. M. Buck — American Sheet & Tin Plate Co.
W. A. Cooper — Alan Wood Iron & Steel Co.
W. R. Fleming — The Andrews Steel Co.
D. J. McAdam, Jr. — U. S. Navy, Bureau Steam Engineering.
M. E. McDonnell — Pennsylvania Railroad Co.
H. E. Smith — New York Central Railroad Co.
F. B. Wheaton — U. S. Army, Quartermaster's Corps.

NOTES. — GENERAL.

The Following Sheets have been recorded as having Failed in Previous Reports.

Sheets O-13, 14, 15, 16, 19, 21, 23 and 24.
" A-16, 17 and 18.
" Z-421.

— J. A. AUPPERLE —

Sheet Z-109 — Mechanical Damage
" Y-4 — Failed.
" E-16, 18 and 20 — Mechanical D
" H-28 — Mechanical Damage
" K-20 and 21 — Mechanical Da
" K-22 — Bent.
" K-27 — Mechanical Damage.
" K-28 — Bent.
" K-32 — Mechanical Damage.
" U-22 and 23 — Bent.
" U-26 — Hole; Rifle Shot.
" O-17, 18, 20 and 22 — Failed.

TABLE I.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT PITTSBURGH, PA., OCTOBER 11, 1920.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
FORT SHERIDAN, ILL.

EXPOSED APRIL 9, 1917

Condition of Rust: Texture							Color									Adherence								
3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
S	S				M	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				M	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				M	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T

ROW No. 5

Designation: Mark	Sheet No.	Condition of Rust: Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
KK	19	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	20	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	21	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	22	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	23	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	24	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	25	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	26	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
KK*	43	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	44	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	45	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	46	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	47	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	48	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	49	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	50	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
MMT	18	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	19	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	20	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	21	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	22	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	23	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	24	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	25	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	26	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	27	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	28	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
SS	18	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	19	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	20	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	22	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	23	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	24	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	25	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	26	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	27	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
TT	18	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	19	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	20	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	21	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	22	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	23	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	24	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	25	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	26	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	27	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	28	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
Y†	6	C	C	M	C				C	M	M	M	M	M				M	D	L	L	T	L				L	T
	8	C	C	M	C				C	M	M	M	M	M				M	D	L	L	T	L				L	T

ROW No. 6

Designation: Mark	Sheet No.	Condition of Rust: Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
UU	18	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	19	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	20	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	22	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	23	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	24	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	25	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	26	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	27	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	28	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
VV	23	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	24	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	25	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	26	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	27	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	28	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL					L	T
	29	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	30	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	31	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	32	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	33	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	34	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	35	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	36	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	37	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	38	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
XX	18	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	19	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	20	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	21	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	22	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	23	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	24	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	25	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	26	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	27	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	28	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
ZZ	5	C	C	VC	VC				C	M	L	L	M	L				M	D	L	L	L	L				L	T
	7	C	C	VC	VC				C	M	L	L	M	L				M	D	L	L	L	L				L	T
	308	VS	VS	VS	M				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	309	VS	VS	VS	M				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	305	VS	S	S					S	M	D	D	M	D				D	D	T	T	T	T				T	T
	306	VS	S	S					S	M	D	D	M	D				D	D	T	T	T	T				T	T
	610	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	611	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T

ROW No. 7

Designation: Mark	Sheet No.	Condition of Rust: Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
ZZ	106	VS	VS	S	S				VS	S	D	D	D	D				M	D	T	T	T	T				T	T
	205	VS	VS	VS	S				VS	S	D	D	D	D				M	D	T	T	T	T				T	T
	206	VS	VS	VS	S				VS	S	D	D	D	D				M	D	T	T	T	T				T	T
	420	VS	M	S	M				M	M	D	D		M				M	D	T	T	T	T				T	T
	422	VS	M	S	M				M	M	D	D		M				M	D	T	T	T	T				T	T
	712	VS	VS	VS	M				S	M	D	D		D					D	T	T	T	T				T	T
	713	VS	VS	VS	M				S	M	D	D		D					D	T	T	T	T				T	T
OO	16	C	C	C	C				M	C	M	M	L	L					D	L	L	L	L				L	T
	17	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	18	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	19	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	20	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	21	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	22	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	23	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
	24	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L				L	T
CCC	16	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	17	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	18	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	19	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	20	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	21	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	22	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	23	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
	24	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L				L	T
A	19	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	20	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	21	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	22	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	23	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	24	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	25	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	26	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	27	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	28	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	29	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
	30	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L				L	T
B	12	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T				L	T
	13	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T				L	T
	14	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T				L	T
	15	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T				L	T
	16	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T				L	T
	29	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T				L	T
	30	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T				L	T
	31	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T				L	T
	32	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T				L	T
	33	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T				L	T
Z	710	VS	VS	VS	S				S	S	D	D	D	D				D	D	T	T	T	T				T	T

* Sand Blasted.

† Open Annealed. Exposed 6-13-17.

Damage.

anical Damage.

amage.

nical Damage.

amage.

amage.

not.

ailed.

— D. M. BUCK —

Sheet Y-4- Failed.
" O-17, 18, 20 and 22-Failure.

— W. A. COOPER —

Sheet Y-4-Failed.
Sheets O-17, 18, 20 and 22-Failed.
The Following Sheets are Dented,-Many of them From below:
B-10; O-16; M-15 and 16; A-21, 22, 24 and 27; B-15, 16, 30 and 32; C-19 and 30; E-16, 18, 20 and 23; H-28 and 35; I-24, 26, 36 and 37; Z-605 and 709; K-22, 27 and 32; M-20, 22 and 24; T-23; Z-508.
The Following Sheets are Bent:
C-8; T-17; U-15; C-9, 18 and 19; K-20 and 22; U-22 and 23.
Sheet Z-109-Damaged by Hammer Blow from beneath.
" T-20-Badly Bent.
" U-25-Bullet Hole.
" U-26-2 Bullet Holes.

— W. R. FLEMING —

Sheet Y-4-Failed.
Sheets O-17, 18, 20 and 22 Failed.
The Following Sheets are Reported as Damaged.
T-17, U-15, Z-109; C-9, 18, 19, 27, 30 and 31; E-16, 18, 20, 21 and 23; H-23 and 29; I-24, 26, 36 and 37;
Z-605 and 709.
K-20, 21, 22, 23 and 27. M-20, 22, 23 and 24;
T-20 and 23.

J. H. GIBBON
Did not make this

D. J. McADAM
Did not make thi

M. E. McDON
Did not make thi

TABLE I.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT PITTSBURGH, PA., OCTOBER 11, 1920.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
FORT SHERIDAN, ILL.

EXPOSED APRIL 9, 1917

Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
C	C	C	VC				C	C	L	L	L	L				M	M	L	L	L	L				L	T
S	M	S	S				M	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				M	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				M	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
	M	S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	M	S	S				S	M	M	D	D	D				M	D	T	T	T	T				T	T
S	S	S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				D	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	S	S	M				M	M	D	D	D	D				M	D	T	T	T	T				L	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T
S	VS	S	M				S	S	D	D	D	D				D	D	T	T	T	T				T	T

ROW No. 5

Designation: Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
KK	19	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	20	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	21	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	22	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	23	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	24	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	25	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	26	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
NN*	43	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	44	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	45	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	46	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	47	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	48	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	49	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	50	VS	VS	VS	S				S	M	D	D	D	D				D	D	T	T	T	T				T	T
MM†	18	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	19	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	20	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	21	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	22	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	23	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	24	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	25	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	26	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	27	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
	28	M	S	M	M				M	C	M	D	M	D				M	D	T	T	T	T				L	T
SS	18	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	19	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	20	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	22	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	23	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	24	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	25	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	26	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
	27	C	C	C	VC				C	C	L	L	L	L				L	M	L	L	L	L				L	T
TT	18	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	19	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	20	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	21	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	22	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	23	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	24	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	25	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	26	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	27	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
	28	S	S	M	M				M	M	D	D	D	D				M	D	T	T	T	T				T	T
Y‡	6	C	C	M	C				C	M	M	M	M	M				M	D	L	L	T	L				L	T
	8	C	C	M	C				C	M	M	M	M	M				M	D	L	L	T	L				L	T

ROW No. 6

Designation: Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
UU	18	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	19	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	20	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	22	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	23	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	24	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	25	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	26	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	27	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
	28	M	S	M	M				M	M	M	D	M	D				M	D	T	T	TL	T				L	T
VV	23	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	24	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	25	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	26	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	27	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	28	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	29	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	30	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	31	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	32	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	33	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	34	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	35	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	36	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	37	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
	38	M	S	M	C				M	M	M	D	M	M				M	D	T	T	TL	L				L	T
XX	18	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	19	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	20	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	21	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	22	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	23	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	24	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	25	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	26	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	27	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
	28	C	C	C	VC				C	C	M	M	L	L				L	D	L	L	L	L				L	T
ZZ	5	C	C	VC	VC				C	M	L	L	M	L				M	D	L	L	L	L				L	T
	7	C	C	VC	VC				C	M	L	L	M	L				M	D	L	L	L	L				L	T
	308	VS	VS	VS	M				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	309	VS	VS	VS	M				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	305	VS	S	S					S	M	D	D	M	D				D	D	T	T	T	T				T	T
	306	VS	S	S					S	M	D	D	M	D				D	D	T	T	T	T				T	T
	610	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	611	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T

ROW No. 7

Designation: Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming
ZZ	106	VS	VS	S	S				VS	S	D	D	D	D				M	D	T	T	T	T
	205	VS	VS	VS	S				VS	S	D	D	D	D				M	D	T	T	T	T
	206	VS	VS	VS	S				VS	S	D	D	D	D				M	D	T	T	T	T
	420	VS	M	S	M				M	M	D	D		M				M	D	T	T	T	T
	422	VS	M	S	M				M	M	D	D		M				M	D	T	T	T	T
	212	VS	VS	VS	M				S	M	D	D		D					D	T	T	T	T
	213	VS	VS	VS	M				S	M	D	D		D					D	T	T	T	T
OO	16	C	C	C	C				M	C	M	M	L	L					D	L	L	L	L
	17	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	18	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	19	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	20	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	21	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	22	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	23	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
	24	C	C	C	C				M	C	M	M	L	L				M	D	L	L	L	L
CCC	16	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	17	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	18	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	19	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	20	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	21	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	22	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	23	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
	24	M	M	C	C				M	C	D	M	L	L				M	D	T	L	L	L
A	19	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	20	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	21	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	22	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	23	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	24	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	25	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	26	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	27	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	28	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	29	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
	30	C	VC	C	VC				C	C	M	L	M	L				M	D	L	L	TL	L
B	12	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T
	13	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T
	14	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T
	15	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T
	16	S	M	M	M				M	C	D	M	M	D				M	D	T	L	TL	T
	29	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T
	30	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T
	31	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T
	32	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T
	33	S	M	M	M				M	M	D	M	M	D				M	D	T	L	TL	T
Z	710	VS	VS	VS	S				S	S	D	D	D	D				D	D	T	T	T	T

* Sand Blasted
† Open Annealed
‡ Exposed 4-12-17

RLE —
nical Damage.
- Mechanical Damage.
nical Damage.
Mechanical Damage.
nical Damage.
nical Damage.
Bent.
Rifle Shot.
22 - Failed.

— D. M. BUCK —
Sheet Y-4 - Failed.
" O-17, 18, 20 and 22 - Failure.

— W. A. COOPER —
Sheet Y-4 - Failed.
Sheets O-17, 18, 20 and 22 - Failed.
The Following Sheets are Dented, - Many of them from below:
B-10; O-16; M-15 and 16; A-21, 22, 24 and 27; B-15, 16, 30 and 32; C-19 and 30; E-16, 18, 20 and 23; H-28 and 35; I-24, 26, 36 and 37; Z-605 and 709; K-22, 27 and 32; M-20, 22 and 24; T-23, Z-508.
The Following Sheets are Bent:
C-8; T-17; U-15, C-9, 18 and 19, K-20 and 22, U-22 and 23.
Sheet Z-109 - Damaged by Hammer Blow from beneath.
" T-20 - Badly Bent.
" U-25 - Bullet Hole.
" U-26 - 2 Bullet Holes.

— W. R. FLEMING —
Sheet Y-4 - Failed.
Sheets O-17, 18, 20 and 22 Failed.
The Following Sheets are Reported as Damaged.
T-17, U-15, Z-109, C-9, 18, 19, 27, 30 and 31, E-16, 18, 20, 21 and 23, H-23 and 29, I-24, 26, 36 and 37, Z-605 and 709.
K-20, 21, 22, 23 and 27. M-20, 22, 23 and 24, T-20 and 23.

Did n
Did n
Did n

PLATE I.
PROC. AM. SOC. TEST. MATS.
VOL. 21.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

Weather Fair

Adherence								
1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
T	T	T	T				T	T
T	T	T	T				T	T
T	T	T	T				T	T
T	T	T	T				T	T
T	T	T	T				T	T
T	T	T	T				T	T
T	T	T	T				T	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
L	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
T	L	L	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
L	L	TL	L				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	L	TL	T				L	T
T	T	T	T				T	T

ROW No. 8

DESIGNATION		CONDITION OF RUST																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
C	9	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	10	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	18	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	19	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	27	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	28	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	29	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	30	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
	31	M	C	M	M				M	M	M	L	M	M				M	D	T	L	TL	T				L	T
D	24	M	C	M	C				C	C	M	L	L	L				L	D	T	L	TL	L				L	T
	25	M	C	M	C				C	C	M	L	L	L				L	D	T	L	TL	L				L	T
	28	M	C	M	C				C	C	M	L	L	L				L	D	T	L	TL	L				L	T
E	16	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	17	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	18	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	19	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	20	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	21	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	22	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	23	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	24	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
H	23	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	24	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	25	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	28	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	29	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	33	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	35	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	36	S	S	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
I	22	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	23	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	24	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	25	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	26	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	27	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	28	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	29	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	30	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	31	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	32	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	33	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	34	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	35	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	36	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	37	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
Z	605	VS	VS	VS	M				S	M	D	D	D	D				D	D	T	T	T					T	T
	606	VS	VS	VS	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	709	VS	VS	VS	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T

ROW No. 9

DESIGNATION		CONDITION OF RUST																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
K	20	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	21	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	22	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	23	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	24	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	25	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	26	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	27	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	28	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	29	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	30	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	31	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	32	S	VS	S	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
M	18	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	19	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	20	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	21	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	22	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	23	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	24	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	25	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	26	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	27	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
	28	S	M	S	M				S	M	D	D	D	D				D	D	T	T	T	T				T	T
S	18	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	19	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	20	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	21	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	22	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	23	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	24	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	25	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	26	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	27	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
	28	C	C	VC	VC				C	VC	L	L	L	L				L	M	L	L	L	L				L	T
T	18	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	19	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	20	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	21	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	22	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	23	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	24	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	25	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	26	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	27	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
	28	VS	S	M	M				S	C	D	D	M	D				M	D	T	T	T	T				T	T
U	18	M	S	M	C				S	C	M	D	M	M				M	D	T	T	T	T				T	T
	19	M	S	M	C				S	C	M	D	M	M				M	D	T	T	T	T				T	T
	20	M	S	M	C				S	C	M	D	M	M				M	D	T	T	T	T				T	T
	21	M	S	M	C				S	C	M	D	M	M				M	D	T	T	T	T				T	T

ROW No. 10

DESIGNATION		CONDITION OF RUST																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
U	22	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
	23	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
	24	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
	25	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
	26	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
	27	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
	28	M	S	M	M				S	M	M	D	M	M				D	D	T	T	T	T				T	T
V	18	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	19	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	20	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	21	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	22	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	23	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	24	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	25	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	26	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	27	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
	28	M	S	M	M				S	M	M	D	M	M				M	D	T	T	T	T				T	T
X	18	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	19	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	20	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	21	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	22	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	23	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	24	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	25	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	26	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	27	C	C	C	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
	28	C	C	[illegible]	C				M	C	L	L	L	L				M	M	L	L	TL	L				L	T
O	16				C					C				L					M				L					T
	17				C					C				L					M				L					T
	18				C					C				L					M				L					T
	19				C					C				L					M				L					T
	20				C				C	C				L				M	M				L				L	T
	21				C					C				L					M				L					T
	22	C			C					C	M			L					M	L			L					T
	23				C					C				L					M				L					T
	24				C					C				L					M				L					T
Z	119	VS	VS	S	S				VS	M	D	D	D	D				D	D	T	T	T	T				T	T
	207	VS	VS	S	S				VS	M	D	D	D	D				D	D	T	T	T	T				T	T
	208	VS	VS	S	S				VS	M	D	D	D	D				D	D	T	T	T	T				T	T
	306	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	308	VS	VS	VS	S				VS	S	D	D	D	D				D	D	T	T	T	T				T	T
	420	VS	C	M					C	C	D	L	M	L				M	D	T	L	TL	L				L	T
	421				C					C				L					D				L					T
	506	S	VS	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T
	508	S	VS	S	M				S	M	D	D	D	D				M	D	T	T	T	T				T	T

J. H. GIBBONEY.
Did not make this Inspection.

D. J. MCADAM, JR.
Did not make this Inspection.

M. E. MCDONNELL.
Did not make this Inspection.

— H. E. SMITH. —
Sheet Y-4. Failed. 2 Small Holes near Bottom.
Sheets O-17, 18, 20 and 22 Failed.
" T-17, U-15 and X-17. Top End Bent down.
" C-9. Somewhat Bent down at Rail, also
Shallow Dent near Bottom.
Sheet K-20 Bent Down Top and Bottom.
" K-22 Bent Down at Bottom.
" K-32- Dent ½ up from Bottom.
" T-20- Bent Down at Top.
" U-22- Slight Bent.
" U-25- Bullet Hole.
" U-26- Two Bullet Holes.
Sheets O-17 and 20 Badly Bent Down at Top.
" O-22, 23 and 24; Bent Down near Bottom.

— F. B. WHEATON —
Sheet Y-4 - Failed.
Sheets O-17, 18, 20 and 22 Failed.
" OO-18, 21 and 22. Blisters.
Sheet H-28 - Bumps.
" C-9. Bent Slightly.
Sheets K-20 and 22. Bent.
Sheet K-21- Bullet Holes.
" T-20- Bent Top.
" U-25- Bullet Holes.
" U-26- Two Bullet Holes, 1 Dent.
Sheets O-17, 20, 21, 23 and 24 Bent.

James H. Gibboney
Chairman Inspection Committee

Date of Inspection *Oct. 12, 1920.*

ROW No. 1

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	21																											
	22																											
	23																											
	24																											
BB	5	S	M	C	M			S	S	S	D	D	D	D			D	M	D	T	L	L	T			T	T	T
	19	S	M	C	M			S	S	S	D	D	D	D			D	M	D	T	L	L	T			T	T	T
	20	C	C	VC	M			M	M	M	D	M	D	D			M	M	D	T	L	L	T			L	L	T
	21	C	C	VC	M			M	M	M	D	M	D	D			M	M	D	T	L	L	T			L	L	T
CC	15	C	C	C	C			M	M	M	M	L	L	M			M	L	D	L	L	L	L			L	L	T
	16	C	C	C	C			M	M	M	M	L	L	M			M	L	D	L	L	L	L			L	L	T
	17	C	C	C	C			M	M	M	M	L	L	M			M	L	D	L	L	L	L			L	L	T
	18	C	C	C	C			M	M	M	M	L	L	M			M	L	D	L	L	L	L			L	L	T
DD	25	C	VC	VC	VC			C	C	C	L	L	L	L			L	L	D	L	L	L	L			L	L	L
	26	C	VC	VC	VC			C	C	C	L	L	L	L			L	L	D	L	L	L	L			L	L	L
	27	C	VC	VC	VC			C	C	C	L	L	L	L			L	L	D	L	L	L	L			L	L	L
	28	C	VC	VC	VC			C	C	C	L	L	L	L			L	L	D	L	L	L	L			L	L	L
EE*	13	S	M	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	L	T
	14	S	M	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	L	T
	15	S	M	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	L	T
	16	S	M	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	L	T
HH	19	S	S	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	20	S	S	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	21	S	S	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	22	S	S	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
II	20	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	21	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	22	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	23	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
KK	6	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	7	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	8	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	27	VS	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
MM*	29	M	C	M	C			M	M	M	M	D	M	M			M	M	D	T	L	TL	L			T	L	L
	30	M	C	M	C			M	M	M	M	D	M	M			M	M	D	T	L	TL	L			T	L	L
	31	M	C	M	C			M	M	M	M	D	M	M			M	M	D	T	L	TL	L			T	L	L
	32	M	C	M	C			M	M	M	M	D	M	M			M	M	D	T	L	TL	L			T	L	L
SS	29																											
	30																											
	31																											
	32																											
TT	29	S	S	M	S			VS	VS	S	D	D	D	D			D	M	D	T	T	TL	T			T	T	T
	30	S	S	M	S			VS	VS	S	D	D	D	D			D	M	D	T	T	TL	T			T	T	T
	31	S	S	M	S			VS	VS	S	D	D	D	D			D	M	D	T	T	TL	T			T	T	T
	32	S	S	M	S			VS	VS	S	D	D	D	D			D	M	D	T	T	TL	T			T	T	T
UU	29	M	S	M	M			VS	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
	30	M	S	M	M			VS	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
	31	M	S	M	M			VS	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
	32	M	S	M	M			VS	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
VV	39	M	S	M	M			S	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
	40	M	S	M	M			S	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
	41	M	S	M	M			S	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
	42	M	S	M	M			S	S	M	M	D	D	D			D	M	D	T	T	TL	T			T	T	T
XX	29																											
	30																											
	31																											
	32																											
OO	25	C	VC	VC	VC			VC	C	C	M	M	M	L			M	M	M	T	L	L	L			L	L	L
	26	C	VC	VC	VC			VC	C	C	M	M	M	L			M	M	M	T	L	L	L			L	L	L
	27	C	VC	VC	VC			VC	C	C	M	M	M	L			M	M	M	T	L	L	L			L	L	L
	28	C	VC	VC	VC			VC	C	C	M	M	M	L			M	M	M	T	L	L	L			L	L	L
CCC	3	M	S	M	C			S	S	M	M	M	L	D			D	D	D	T	T	T	T			T	T	T
	4	M	S	M	C			S	S	M	M	M	L	D			D	D	D	T	T	T	T			T	T	T
	5	M	S	M	C			S	S	M	M	M	L	D			D	D	D	T	T	T	T			T	T	T
	6	M	S	M	C			S		M	M	M	L	D			D	D	D	T	T	T	T			T	T	T
ZZ	5																											
	10																											
	14																											
	107	M	S	S	S			S	VS	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	310	VS	VS	VS	VS			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	311	VS	VS	VS	VS			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T

* Open Annealed

ROW No. 2

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
A	31																											
	32																											
	33																											
	34																											
B	17		M		C							D		D							T		T					
	18		M		C							D		D							T		T					
	19	S	M	M	C			M	M	M	D	D	D	D			D	D	D	T	T	T	T			T	T	L
	20	S	M	M	C			M	M	M	D	D	D	D			D	D	D	T	T	T	T			T	T	L
C	11		M		C			M				D		D			M				T		T			T		
	12	S	M	M	C			M	M		D	D	D	D			M	D		T	T	T	T			T	T	
	13		M		C			M				D		D			M				T		T			T		
	14		M		C			M				D		D			M				T		T			T		
D	30																											
	31																											
	33																											
	34																											
F	25																											
	26																											
	27																											
	28																											
H	39	S	S	S	S			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	40	S	S	S	S			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	41	S	S	S	S			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	42	S	S	S	S			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
I	38	VS	VS	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	39	VS	VS	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	40	VS	VS	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	41	VS	VS	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
K	33	S	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	34	S	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	35	S	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	36	S	VS	S	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
M	29	M	M	M	M			M	S	M	M	D	D	M			D	D	D	T	T	T	L			T	L	T
	30	M	M	M	M			M	S	M	M	D	D	M			D	D	D	T	T	T	L			T	L	T
	31	M	M	M	M			M	S	M	M	D	D	M			D	D	D	T	T	T	L			T	L	T
	32				M							D		M							T		L					
S	29																											
	30																											
	31																											
	32																											
T	29	M		M				M		M	M		D				D		D	T		T				T		T
	30	M		M				M		M	M		D				D		D	T		T				T		T
	31	M		M				M		M	M		D				D		D	T		T				T		T
	32	M									M									T								
U	29		C		M							D		M							TL		L					
	30		C		M							D		M							TL		L					
	31	M	C	M	M			M	M	M	M	D	D	M			D	M	D	T	TL	T	L			T	L	T
	32	M	C	M	M			M	M	M	M	D	D	M			D	M	D	T	TL	T	L			T	L	T
V	29		C		M							D		M							TL		L					
	30	M	C	M	M			M	M	M	M	D	D	M			D	D	D	T	TL	L	L			L	L	T
	31	M	C	M	M			M	M	M	M	D	D	M			D	D	D	L	TL	L	L			L	L	T
	32	M	C	M	M			M	M	M	M	D	D	M			D	D	D	L	TL	L	L			L	L	T
X	29																											
	30																											
	31																											
	32																											
O	25																											
	26																											
	27																											
	28																											
Z	6																											
	7																											
	11																											
	111	VS	S	M	VS			VS	S	S	D	D	D	D			D	D	D	T	L	T	T			T	T	T
	112	VS	S	M	VS			VS	S	S	D	D	D	D			D	D	D	T	L	T	T			T	T	T
	113	VS	S	M	VS			VS	S	S	D	D	D	D			D	D	D	T	L	T	T			T	T	T
	200	VS	VS	S	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	213	VS	VS	S	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	214	VS	VS	S	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	310	VS	VS	VS	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T

ROW No. 3

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	25																											
	26																											
	27																											
	28																											
	29																											
	30																											
AA*	50																											
	51																											
	52																											
	53																											
	54																											
	55																											
	56																											
BB	22	C	C	C	VC			C	M	C	M	D	D	D			D	D	M	T	L	L	L			L	L	T
	23	C	C	C	VC			C	M	C	M	D	D	D			D	D	M	T	L	L	L			L	L	T
	24	C	C	C	VC			C	M	C	M	D	D	D			D	D	M	T	L	L	L			L	L	T
	40	S	M	M	M			M	M	S	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	41	S	M	M	M			M	M	S	M	D	D	D			D	D	D	T	T	T	L			T	L	T
BB*	33	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	34	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	35	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	36	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	50	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	51	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	52	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
	53	S	M	M	M			M	M	M	M	D	D	D			D	D	D	T	T	T	L			T	L	T
CC	7	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
	19	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
CC*	31	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
	32	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
	33	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
	34	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
	35	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
	36	C	C	VC	C			C	C	C	M	M	M	M			D	D	D	L	L	L	L			L	L	T
DD	8	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	9	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	10	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	29	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	30	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	31	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
DD*	47	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	48	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	49	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	54	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	55	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	56	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	57	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
	58	VC	VC	VC	VC			VC	VC	VC	M	M	L	L			M	D	M	L	L	L	L			L	L	L
EE†	17	M	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	18	M	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
EE*†	31	S	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	32	S	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	33	S	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	34	S	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	35	S	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
	36	S	S	S	S			S	S	S	M	D	D	D			D	D	D	T	T	T	T			T	T	T
HH	23	S	S	S	M			VS	M	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	24	S	S	S	M			VS	M	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	25	S	S	S	M			VS	M	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	26	S	S	S	M			VS	M	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
HH*	43	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	44	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	45	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	46	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	47	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	48	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T			T	L	T
	49	S	S	S	M			VS	S	M	M	D	D	D			D	D	D	T	T	T	T					
II	24	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	26	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	27	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	28	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	29	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T

* Sand Blasted

† Open Annealed

ROW No. 4

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming
II*	48	VS	VS	VS	VS
	49	VS	VS	VS	VS
	50	VS	VS	VS	VS
	51	VS	VS	VS	VS
	52	VS	VS	VS	VS
	53	VS	VS	VS	VS
	54	VS	VS	VS	VS
	55	VS	VS	VS	VS
	56	VS	VS	VS	VS
KK	28	S	VS	VS	S
	29	S	VS	VS	S
	30	S	VS	VS	S
	31	S	VS	VS	S
	32	S	VS	VS	S
	33	S	VS	VS	S
	34	S	VS	VS	S
KK*	51	S	VS	VS	S
	52	S	VS	VS	S
	53	S	VS	VS	S
	54	S	VS	VS	S
	55	S	VS	VS	S
	56	S	VS	VS	S
	57	S	VS	VS	S
	58	S	VS	VS	S
MM†	33	C	M	M	C
	34	C	M	M	C
	35	C	M	M	C
	36	C	M	M	C
	37	C	M	M	C
	38	C	M	M	C
	39	C	M	M	C
	40	C	M	M	C
	41	C	M	M	C
	42	C	M	M	C
SS	33				
	34	VC		VC	
	35				
	36	VC		VC	
	37	VC		VC	
	38	VC		VC	
	39				
	40				
	41	VC		VC	
	42	VC		VC	
TT	33	S	S	S	M
	34	S	S	S	M
	35	S	S	S	M
	36	S	S	S	M
	37	S	S	S	M
	38	S	S	S	M
	39	S	S	S	M
	40	S	S	S	M
	41	S	S	S	M
	42	S	S	S	M
UU	33	S	S	S	M
	34	S	S	S	M
	35	S	S	S	M
	36	S	S	S	M
	37	S	S	S	M
	38	S	S	S	M
	39	S	S	S	M
	40	S	S	S	M
	41	S	S	S	M
	42	S	S	S	M
VV	43	M	S	S	M
	44	M	S	S	M
	45	M	S	S	M
	46	M	S	S	M
	47	M	S	S	M
	48	M	S	S	M
	49	M	S	S	M
	50	M	S	S	M
	51	M	S	S	M

* Sand Blasted

† Open Annealed

CONDITION OF RUST.

Texture	Color	Adherence
VS—Very Smooth	L—Light	T—Tight
S—Smooth	M—Medium	L—Loose
M—Medium	D—Dark	
C—Coarse		
VC—Very Coarse		

— INSPECTION COMMITTEE —

J. H. Gibboney, Chairman — Norfolk & Western Ry. Co.
J. A. Aupperle — American Rolling Mill Co.
D. M. Buck — American Sheet & Tin Plate Co.
W. A. Cooper — Alan Wood Iron & Steel Co.
W. R. Fleming — The Andrews Steel Co.
D. J. Mc Adam Jr. — U. S. Navy, Bureau Steam Engineering.
M. E. Mc Donnell — Pennsylvania Railroad Co.
H. E. Smith — New York Central Railroad Co.
F. B. Wheaton — U. S. Army, Quartermaster's Corps.

GENERAL NOTES:

The Following Sheets have been Recorded a

A – 31 to 47 incl.
B – 17, 18 and 35 to 38 incl.
C – 11, 13, 14, 20, 21, 22, 32, 34 and 35.
D – 30 to 40 incl.
E – 25 to 36 incl.
M – 32, 36 and 40.
O – 25 to 36 incl.
S – 29 to 42 incl.
XX – 29, 30, 31, 32 and 41.

T – 3
U – 2
V – 2
X – 2
Y – 7
Z – 6
AA – 2
SS – 2
ZZ – 8

TABLE II.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT PITTSBURGH, PA., OCTOBER 12, 1920.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-3 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
PITTSBURGH, PA.

EXPOSED DECEMBER 12, 1916

Condition of Rust																										
Texture									Color									Adherence								
1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
C	M	M	C			M	M	M	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	M	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	M	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	M	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	M	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	C	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	C	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	C	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	C	M	D	D	M			M	D	D	L	L	L	L			L	L	T
C	M	M	C			M	M	C	M	D	D	M			M	D	D	L	L	L	L			L	L	T
VC		VC				VC	VC	VC	L		L				M	D	M	L						L	T	L
VC		VC				VC		VC	L		L				M		M	L						L		L
VC		VC				VC		VC	L		L				M		M	L						L		L
VC		VC				VC		VC	L		L				M		M	L						L		L
VC		VC				VC		VC	L		L				M		M	L						L		L
VC		VC				VC		VC	L		L				M		M	L						L		L
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	M	D	D	D			D	D	D	T	T	T	T			L	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
M	S	S	M			S	S	M	M	D	D	D			D	D	D	T	T	T	T			T	T	T
									M	D	D	D			D	D	D	T	T	T	T			T	T	T

ROW No. 5

Designation		Condition of Rust																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
XX	33	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	34	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	35	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	36	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	37	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	38	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	39	VS	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	40	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
	41		VC		VC							D		M							L		L					
	42	VC	VC	VC	VC			VC	VC	VC	M	D	D	M			M	M	M	L	L	L	L			L	T	L
ZZ	208	VS	S	VS	VS			VS	S	S	M	D	D	D			M	D	D	T	T	T	T			T	T	T
	209	VS	S	VS	VS			VS	S	S	M	D	D	D			M	D	D	T	T	T	T			T	T	T
	213	VS	S	VS	VS			VS	S	S	M	D	D	D			M	D	D	T	T	T	T			T	T	T
	214	VS	S	VS	VS			VS	S	S	M	D	D	D			M	D	D	T	T	T	T			T	T	T
	426	C	C	C	C			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	427	C	C	C	C			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	507	S	S	S	S			VS	S	S	D	D	D	D			D	M	D	T	T	T	T			T	T	T
	510	S	S	S	S			VS	S	S	D	D	D	D			D	M	D	T	T	T	T			T	T	T
	509	S	S	S	S			VS	S	S	D	D	D	D			D	M	D	T	T	T	T			T	T	T
	612		VS	VS	VS			VS	S	VS		D	D	D			D	D	D		T	T	T			T	T	T
	614	S	VS	VS	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	615	S	VS	VS	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	714	S	VS	VS	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	715	S	VS	VS	VS			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
OO	29	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	30	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	31	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	32	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	33	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	34	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	35	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
	36	C	C	VC	VC			C	C	C	M	D	M	L			M	D	D	T	L	L	L			L	L	T
CCC	5	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	6	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	7	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	8	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	9	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	10	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	11	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
	12	M	M	M	C			M	M	M	M	D	M	M			M	D	D	T	L	L	L			L	T	T
A	35																											
	36																											
	37																											
	38																											
	39																											
	40																											
	41																											
	42																											
	43																											
	44																											
	45																											
	46																											
	47																											
B	21	M		M	C			M	M	M	M		D	D			D	M	D	T		TL	L			L	L	T
	22	M		M	C			M	M	M	M		D	D			D	M	D	T		TL	L			L	L	T
	23			M	C			M	M	M			D	D			D	M	D			TL	L			L	L	T
	24	M		M	M			S	M	M	M		D	D			D	M	D	T		TL	T			L	L	T
	25				C			M						D			D						L			L		
	26				C			M						D			D						L			L		
	27				C			M						D			D						L			L		
	28				C			M						D			D						L			L		
	29	M		M	M			S		S	M		D	D			D		D	T		TL	L			L		T
C	20							M									M									L		
	21							M									M									L		
	22							M									M									L		
	32							M									M									L		
	33	C		M				M		C	L		D				M		D	L		L				L		T
	34							M									M									L		
	35							M									M									L		

ROW No. 6

Designation		Condition of Rust																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
D	35																											
	36																											
	37																											
	39																											
	40																											
E	29																											
	30																											
	31																											
	32																											
	33																											
	34																											
	35																											
	36																											
H	43	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	45	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	47	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	49	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	50	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	53	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	54	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	55	S	S	S	M			S	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
I	42	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	43	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	44	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	45	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	46	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	47	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	48	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	49	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	50	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	51	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	52	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	53	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	54	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	55	VS	VS	VS	S			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
K	37	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	38	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	39	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	40	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	41	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	42	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	43	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	44	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	45	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	46	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	47	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
	48	S	VS	VS	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T			T	T	T
M	33	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	34	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	35	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	36		M		C							D		D							T		T					
	37	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	38	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	39	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	40	M	M	M	C			S	M	M	M	D	D	D			D	D	D	T	T	TL	T			T	L	T
	41		M	M	C			S	M	M		D	D	D			D	D	D		T	TL	T			T	L	T
	42		M		C			S				D		D			D				T		T			T		
S	33																											
	34																											
	35																											
	36																											
	37																											
	38																											
	39																											
	40																											
	41																											
	42																											

ROW No. 7

Designation		Condition of Rust																				
Mark	Sheet No.	Texture									Color												
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4
T	33																						
	34	M		C				S	M	M	M		D				D	D	D	T		TL	
	35																						
	36																						
	37																						
	38																						
	39																						
	40	M		C				S	M	M	M		D				D	D	D	T		TL	
	41	M		C				S	M	M	M		D				D	D	D	T		TL	
	42	M		C				S	M	M	M		D				D	D	D	T		TL	
U	33	M		C	M			M	M	M	M		D	D			M	D	D	T		TL	T
	34	M		C	M			M	M	M	M		D	D			M	D	D	T		TL	T
	35	M		C	M			M	M	M	M		D	D			M	D	D	T		TL	T
	36	M		C	M			M	M	M	D		D	D			M	D	D	T		TL	T
	37	M		C	M			M	M	M	D		D	D			M	D	D	T		TL	T
	38			C	M			M	M	M			D	D			M	D	D			TL	T
	39	M		C	M			M	M	M	D		D	D			M	D	D	T		TL	T
	40	M			M						D			D						T			T
	41				M									D									T
	42			C	M			M	M	M			D	D			M	D	D			TL	T
V	33	M		C					M	M	M		D					D	D	L		L	
	34	M		C					M	M	M		D					D	D	L		L	
	35	M		C					M	M	M		D					D	D	L		L	
	36																						
	37																						
	38	M		C					M	M	M		D					D	D	L		L	
	39																						
	40	M		C					M	M	M		D					D	D	L		L	
	41			C					M	M			D					D	D			L	
	42																						
X	33																						
	34																						
	35																						
	36																						
	37																						
	38																						
	39																						
	40																						
	41																						
	42																						
Z	214	VS	S	S	VS			VS	S	VS	D	D	D	D			D	D	D	T	T	T	T
	422	C			M						M			D						L			L
	423	C			M						M			D						L			L
	424	C			M						M			D						L			L
	208	S	S	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T
	213	S	S	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T
	215	VS	S	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T
	507	VS	S	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T
	508	VS	S	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T
	509	VS	S	S	S			VS	S	S	D	D	D	D			D	D	D	T	T	T	T
	712	VS	VS	VS	VS			VS	VS	VS	D	D	D	D			D	D	D	T	T	T	T
	714	VS	VS	VS	VS			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T
	715	VS	VS	VS	VS			VS	VS	S	D	D	D	D			D	D	D	T	T	T	T
																				T	T	T	T
O	29																						
	30																						
	31																						
	32																						
	33																						
	34																						
	35																						
	36																						
Y*	7																						
	8																						
	9																						
YY*	7	VC	VC	VC	VC			VC	VC	VC	M	M	M	L			M	D	M	L	L	L	L
	8	VC	VC	VC	VC			VC	VC	VC	M	M	M	L			M	D	M	L	L	L	L
	9	VC	VC	VC	VC			VC	VC	VC	M	M	M	L			M	D	M	L	L	L	L

* Exposed 6-5-17.

corded as Failures in Previous Reports:
T – 32, 33, 35, 36, 37, 38 and 39.
U – 29, 30, 40 and 41,
V – 29, 36, 37, 39 and 42.
X – 29 to 42 incl.
Y – 7 to 9 incl.
Z – 6, 7, 11, 422, 423 and 424.
AA – 21 to 30 incl., 50 to 56 incl.
SS – 29, 30, 31, 32, 33, 35, 39 and 40.
ZZ – 8, 10 and 14.

— J. A. AUPPERLE —

Sheet CC – 17 Mechanical Damage.
" O – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 41 and 42 – Failed.
" U – 31, 33, 34, 35, 38 and 42 – ".
" SS – 34, 36, 37, 38, 41 " 42 – ".
" B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
" V – 30, 33, 34, 35, 38, 40 and 41 – Failed.
Sheet XX – 36 Failed.

— D. M. BUCK —

Sheet O – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 41 and 42 Failed.
" U – 31, 33, 34, 35, 38 and 42 ".
" SS – 34, 36, 37, 38, 41 and 42 ".
" B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
" V – 30, 33, 34, 35, 38, 40 and 41 Failed.
Sheet XX – 36 Failed.

— W. A. COOPER

Sheet C – 17 Scab on Surfa
" I – 50 Bullet Holes.
" Z – 608 Bent.
" OO – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 4
" U – 31, 33, 34, 35, 38
" SS – 34, 36, 37, 38, 41
" B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
" V – 30, 33, 34, 35, 38,
Sheet XX – 36 Failed.

TABLE II.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT PITTSBURGH, PA., OCTOBER 12, 1920.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
PITTSBURGH, PA.

EXPOSED DECEMBER 12, 1916

ROW No. 5 — ROW No. 6 — ROW No. 7

Designation: Mark, Sheet No. — Condition of Rust: Texture, Color, Adherence

Aupperle, Buck, Cooper, Fleming, Gibboney, McAdam, McDonnell, Smith, Wheaton

1 2 3 4 5 6 7 8 9

* Exposed 6-1-17.

— J. A. AUPPERLE —

Sheet CC – 17 Mechanical Damage.
" O – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 41 and 42 – Failed.
" U – 31, 33, 34, 35, 38 and 42 – "
" SS – 34, 36, 37, 38, 41 " 42 – " .
" B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
" V – 30, 33, 34, 35, 38, 40 and 41 – Failed.
Sheet XX – 36 Failed.

s Failures in Previous Reports:
2, 33, 35, 36, 37, 38 and 39
8, 30, 40 and 41,
8, 36, 37, 39 and 42.
9 to 42 incl.
to 9 incl.
, 7, 11, 422, 423 and 424
to 30 incl., 50 to 56 incl.
9, 30, 31, 32, 33, 35, 39 and 40.
, 10 and 14.

— D. M. BUCK —

Sheet O – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 41 and 42 Failed.
" U – 31, 33, 34, 35, 38 and 42 " .
" SS – 34, 36, 37, 39, 41 and 42 "
" B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
" V – 30, 33, 34, 35, 38, 40 and 41 Failed.
Sheet XX – 36 Failed.

— W. A. COOPER —

Sheet C – 17 Scab on Surface.
" I – 50 Bullet Holes.
" Z – 608 Bent.
" OO – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 41 an
" U – 31, 33, 34, 35, 38 and
" SS – 34, 36, 37, 38, 41 and
" B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
" V – 30, 33, 34, 35, 38, 40
Sheet XX – 36 Failed.

PLATE II.
PROC. AM. SOC. TEST. MATS.
VOL. 21.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

Weather *Fair*

Cooper 3
Fleming 4
Gibboney 5
McAdam 6
McDonnell 7
Smith 8
Wheaton 9

— M. E. McDONNELL —

Sheets MM – 29 to 32 incl. Texture Approaching Coarse.
,, MM – 33 to 42 ,, . ,, ,, ,,
Sheet OO – 27. Failed at Lower End.
Sheets T – 29 to 31 incl. Failed; One Hole.
Sheet T – 34. Failed; Two Holes.
Sheets T – 40 to 42 incl. Failed; One Hole.
,, U – 31, 33, 34, 35, 38 and 42. Failed; One Hole.
,, SS – 34, 36, 37, 38, 41 and 42. Failed.
? ,, B – 21 and 23. Failed.
? Sheet C – 33 - Failed.
,, M – 39 - Failed; One Hole.
,, M – 41 - ,, ; Three Holes.
Sheets V – 30, 35, 38 and 41 - Failed; One Hole.
,, V – 33 and 34 - Failed; Two Holes.
Sheet V – 40 - Failed.
,, XX – 36 - ,, ; One Hole.

It was Difficult to Correctly Rate these Tests for Color on Account of a Black Deposit, presumably from Smoke.

— H. E. SMITH —

Sheet OO – 27 - Failed; Holes near Bottom.
Sheets T – 29, 30 and 31. Failed; Holes near Bottom.
Sheet U – 31 - Failed; Holes near Bottom.
Sheets SS – 34, 36, 37, 38, 41 and 42 - Failed; Holes near Bottom.
,, B – 21 and 23 - Failed near Bottom.
Sheet C – 33 - Failed; Holes near Bottom.
,, M – 39 and 41 - Failed near Bottom.
,, I – 50 and 51 - Hole Due to Mechanical Injury.
,, T – 34, 40, 41 and 42 - Failed near Bottom.
,, U – 33, 34, 35, 38 and 42 - ,, ,, ,, .
,, V – 30, 33, 34, 35 - Failed; Holes near Bottom.
,, V – 38 and 40 - Failed near Bottom.
Sheet V – 40 - Mechanical Injury, also Failed near Bottom.
,, XX – 36 - Failed; Holes near Bottom.

In a large Number of Cases the Dark Color of the Sheets is Due to Soot.

— F. B. WHEATON —

Sheet I – 50 - Bullet Hole.
,, OO – 27 - Failed.
Sheets T – 29, 30, 31, 34, 40, 41 and 42 - Failed.
,, U – 31, 33, 34, 35, 38 and 42 – ,, .
,, SS – 34, 36, 37, 38, 41 and 42 – ,, .
Sheets B – 21 and 23 - Failed.
Sheet C – 33 - Failed.
Sheets M – 39 and 41 - Failed.
,, V – 30, 33, 34, 35, 38, 40 and 41 - Failed.
Sheet XX – 36 - Failed.

ER —
face.
, 41 and 42 Failed.
6 and 42 ,, .
1 and 42 ,, .
d.
8, 40 and 41 Failed.

— W. R. FLEMING —

Sheet OO – 27 Failed.
Sheets T – 29, 30, 31, 34, 40, 41 and 42 Failed.
,, U – 31, 33, 34, 35, 38 and 42 ,, .
,, SS – 34, 36, 37, 38, 41 and 42 ,, .
,, B – 21 and 23 Failed.
Sheet C – 33 Failed.
Sheets M – 39 and 41 Failed.
,, V – 30, 33, 34, 35, 38, 40 and 41 Failed.
Sheet XX – 36 Failed.

— J. H. GIBBONEY AND D. J. McADAM —

Did not make this Inspection.

James H. Gibboney

Date of Inspection Oct. 13, 1920.

ROW No. 1

Mark	Sheet No.	Texture									Color									Adherence								
DESIGNATION		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	1	VC	VC	C	C		M	C	C	C	L	L	M	L		M	L	L	L	L	L	L			L	L	L	L
	2	VC	VC	C	C		M	C	C	C	L	L	M	L		M	L	L	L	L	L	L			L	L	L	L
	3	VC	VC	C	C		M	C	C	C	L	L	M	L		M	L	L	L	L	L	L			L	L	L	L
BB	1	S	S	M	M		M	M	M	M	M	M	D	D		M	M	M	M	T	T	TL			T	T	T	T
	2	S	S	M	M		M	M	M	M	M	M	D	D		M	M	M	M	T	T	TL			T	T	T	T
	3	S	S	M	M		M	M	M	M	M	M	D	D		M	M	M	M	T	T	TL			T	T	T	T
CC	1	M	M	M	M		C	M	C	M	M	L	L	L		L	L	L	L	T	L	TL			L	L	L	T
	2	M	M	M	M		C	M	C	M	M	L	L	L		L	L	L	L	T	L	TL			L	L	L	T
	3	M	M	M	M		C	M	C	M	M	L	L	L		L	L	L	L	T	L	TL			L	L	L	T
DD	1	M	C	C	M		C	M	C	M	M	L	L	L		L	L	M	L	T	L	L			L	L	L	T
	2	M	C	C	M		C	M	C	M	M	L	L	L		L	L	M	L	T	L	L			L	L	L	T
	3	M	C	C	M		C	M	C	M	M	L	L	L		L	L	M	L	T	L	L			L	L	L	T
EE*	1	S	M	M	M		C	S	M	M	M	M	D	L		M	L	M	L	T	T	T			L	T	L	T
	2	S	M	M	M		C	S	M	M	M	M	D	L		M	L	M	L	T	T	T			L	T	L	T
	3	S	M	M	M		C	S	M	M	M	M	D	L		M	L	M	L	T	T	T			L	T	L	T
HH	1	S	S	S	M		S	S	C	M	M	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	2	S	S	S	M		S	S	C	M	M	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	3	S	S	S	M		S	S	C	M	M	D	D	D		M	D	M	M	T	T	T			T	T	L	T
II	1	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	2	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	3	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
KK	1	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	2	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	3	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
MM*	1	M	M	M	M		S	S	C	M	M	D	D	M		M	M	M	D	T	T	TL			T	T	L	T
	2	M	M	M	M		S	S	C	M	M	D	D	M		M	M	M	D	T	T	TL			T	T	L	T
	3	M	M	M	M		S	S	C	M	M	D	D	M		M	M	M	D	T	T	TL			T	T	L	T
NN	1	C	VC	VC	M		C	C	C	C	M	L	L	L		L	L	L	L	T	L	L			L	L	L	T
	2	C	VC	VC	M		C	C	C	C	M	L	L	L		L	L	L	L	T	L	L			L	L	L	T
	3	C	VC	VC	M		C	C	C	C	M	L	L	L		L	L	L	L	T	L	L			L	L	L	T
TT	1	S	S	M	S		C	S	M	M	D	D	D	D		M	L	M	M	T	T	TL			T	T	T	T
	2	S	S	M	S		C	S	M	M	D	D	D	D		M	L	M	M	T	T	TL			T	T	T	T
	3	S	S	M	S		C	S	M	M	D	D	D	D		M	L	M	M	T	T	TL			T	T	T	T
UU	1	M	M	M	M		C	S	C	M	M	D	M	M		M	M	M	M	T	T	TL			L	L	L	T
	2	M	M	M	M		C	S	C	M	M	D	M	M		M	M	M	M	T	T	TL			L	L	L	T
	3	M	M	M	M		C	S	C	M	M	D	M	M		M	M	M	M	T	T	TL			L	L	L	T
VV	1	M	M	M	M		C	M	C	M	M	D	M	M		M	M	M	M	T	T	TL			L	L	L	T
	2	M	M	M	M		C	M	C	M	M	D	M	M		M	M	M	M	T	T	TL			L	L	L	T
	3	M	M	M	M		C	M	C	M	M	D	M	M		M	M	M	M	T	T	TL			L	L	L	T
XX	1	C	C	C	C		C	C	C	C	M	M	M	L		M	L	M	M	T	L	L			L	L	L	L
	2	C	C	C	C		C	C	C	C	M	M	M	L		M	L	M	M	T	L	L			L	L	L	L
	3	C	C	C	C		C	C	C	C	M	M	M	L		M	L	M	M	T	L	L			L	L	L	L
OO	1	C	C	C	C		VC	M	C	M	M	D	D	D		D	D	M	D	T	L	TL			L	L	L	T
	2	C	C	C	C		VC	M	C	M	M	D	D	D		D	D	M	D	T	L	TL			L	L	L	T
	3	C	C	C	C		VC	M	C	M	M	D	D	D		D	D	M	D	T	L	TL			L	L	L	T
OO*†	25	M	C	C	C		VC	M	C	M	M	D	M	L		M	M	M	M	T	L	L			L	L	L	T
	26	M	C	C	C		VC	M	C	M	M	D	M	L		M	M	M	M	T	L	L			L	L	L	T
	27	M	C	C	C		VC	M	C	M	M	D	M	L		M	M	M	M	T	L	L			L	L	L	T

* Open Annealed

† Exposed 11 [illegible]

ROW No. 2

Mark	Sheet No.	Texture									Color									Adherence								
DESIGNATION		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
A	1	S	M	VC	M		M	M	M	M	D	D	D	D		M	L	M	M	T	TL	L			T	L	L	T
	2	S	M	VC	M		M	M	M	M	D	D	D	D		M	L	M	M	T	TL	L			T	L	L	T
	3	S	M	VC	M		M	M	M	M	D	D	D	D		M	L	M	M	T	TL	L			T	L	L	T
B	1	S	S	C	M		C	M	M	C	M	D	D	D		M	M	M	M	T	T	L			L	T	T	T
	2	S	S	C	M		C	M	M	C	M	D	D	D		M	M	M	M	T	T	L			L	T	T	T
	3	S	S	C	M		C	M	M	C	M	D	D	D		M	M	M	M	T	T	L			L	T	T	T
C	1	C	M	C	M		M	M	C	C	L	L	M	L		L	L	L	L	L	T	TL			L	L	L	L
	2	C	M	C	M		M	M	C	C	L	L	M	L		L	L	L	L	L	T	TL			L	L	L	L
	3	C	M	C	M		M	M	C	C	L	L	M	L		L	L	L	L	L	T	TL			L	L	L	L
D	1	C	C	VC	M		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L			L	L	L	L
	5	C	C	VC	M		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L			L	L	L	L
	7	C	C	VC	M		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L			L	L	L	L
E	1	S	S	VS	S		M	S	M	M	M	M	D	M		M	M	M	M	T	T	T			T	T	L	L
	2	S	S	VS	S		M	S	M	M	M	M	D	M		M	M	M	M	T	T	T			T	T	L	L
	3	S	S	VS	S		M	S	M	M	M	M	D	M		M	M	M	M	T	T	T			T	T	L	L
H	1	S	S	VS	M		M	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	L
	2	S	S	VS	M		M	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	L
	3	S	S	VS	M		M	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	L
I	1	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	2	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	3	S	VS	VS	S		S	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
K	1	M	VS	S	S		S	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	2	M	VS	S	S		S	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	3	M	VS	S	S		S	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M	1	M	S	M	M		S	M	M	M	D	D	D	D		D	D	M	D	T	T	TL			T	T	L	T
	2	M	S	M	M		S	M	M	M	D	D	D	D		D	D	M	D	T	T	TL			T	T	L	T
	3	M	S	M	M		S	M	M	M	D	D	D	D		D	D	M	D	T	T	TL			T	T	L	T
N	1	C	VC	VC	M		M	C	C	C	L	L	L	L		L	L	L	L	L	L	L			T	L	L	L
	2	C	VC	VC	M		M	C	C	C	L	L	L	L		L	L	L	L	L	L	L			T	L	L	L
	3	C	VC	VC	M		M	C	C	C	L	L	L	L		L	L	L	L	L	L	L			T	L	L	L
T	1	S	S	C	S		M	S	M	S	D	D	D	D		D	D	D	D	T	T	L			T	T	T	T
	2	S	S	C	S		M	S	M	S	D	D	D	D		D	D	D	D	T	T	L			T	T	T	T
	3	S	S	C	S		M	S	M	S	D	D	D	D		D	D	D	D	T	T	L			T	T	T	T
U	1	S	S	M	M		M	S	M	M	M	D	M	M		M	M	M	M	T	T	TL			T	T	L	T
	2	S	S	M	M		M	S	M	M	M	D	M	M		M	M	M	M	T	T	TL			T	T	L	T
	3	S	S	M	M		M	S	M	M	M	D	M	M		M	M	M	M	T	T	TL			T	T	L	T
V	1	M	S	M	M		C	S	M	M	M	M	M	M		M	M	L	M	T	T	TL			L	L	T	T
	2	M	S	M	M		C	S	M	M	M	M	M	M		M	M	L	M	T	T	TL			L	L	T	T
	3	M	S	M	M		C	S	M	M	M	M	M	M		M	M	L	M	T	T	TL			L	L	T	T
X	1	M	C	C	M		C	C	C	M	M	M	M	M		M	M	L	M	T	L	L			L	L	L	T
	2	M	C	C	M		C	C	C	M	M	M	M	M		M	M	L	M	T	L	L			L	L	L	T
	3	M	C	C	M		C	C	C	M	M	M	M	M		M	M	L	M	T	L	L			L	L	L	T
O	1	S	C	VC	M		C	C	M	M	M	M	M	D		D	D	M	D	T	L	L			L	L	L	T
	2	S	C	VC	M		C	C	M	M	M	M	M	D		D	D	M	D	T	L	L			L	L	L	T
	3	S	C	VC	M		C	C	M	M	M	M	M	D		D	D	M	D	T	L	L			L	L	L	T
Z	1	S	C	C	S		C	M	M	M	M	M	M	D		D	D	M	D	T	L	L			L	L	T	T
	2	S	C	C	S		C	M	M	M	M	M	M	D		D	D	M	D	T	L	L			L	L	T	T
	3	S	C	C	S		C	M	M	M	M	M	M	D		D	D	M	D	T	L	L			L	L	T	T

ROW No. 3

Mark	Sheet No.	Texture									Color									Adherence								
DESIGNATION		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	4	C	VC	VC	C		C	C	M	C	L	L	M	L		M	L	M	M	L	L	L			L	L	L	L
	5	C	VC	VC	C		C	C	M	C	L	L	M	L		M	L	M	M	L	L	L			L	L	L	L
	6	C	VC	VC	C		C	C	M	C	L	L	M	L		M	L	M	M	L	L	L			L	L	L	L
	7	C	VC	VC	C		C	C	C	C	L	L	M	L		M	L	M	M	L	L	L			L	L	L	L
	8	C	VC	VC	C		C	C	C	C	L	L	M	L		M	L	M	M	L	L	L			L	L	L	L
	9	C	VC	VC	C		C	C	C	C	L	L	M	L		M	L	M	M	L	L	L			L	L	L	L
AA*	31	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	32	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	33	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	34	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	35	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	36	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	37	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	38	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
	39	C	C	VC	C		C	C	C	C	L	M	M	L		M	L	M	M	L	L	L			L	L	L	T
BB	10	M	M	C	M		M	M	M	M	M	D	D	M		D	L	M	D	T	T	TL			T	T	T	T
	11	M	M	C	M		M	M	M	M	M	D	D	M		D	L	M	D	T	T	TL			T	T	T	T
	12	M	M	C	M		M	M	M	M	M	D	D	M		D	L	M	D	T	T	TL			T	T	T	T
	13	M	M	C	M		M	M	M	M	M	D	D	M		D	L	M	D	T	T	TL			T	T	T	T
	14	M	M	C	M		M	M	M	M	M	D	D	M		D	L	M	D	T	T	TL			T	T	T	T
	37	M	M	C	M		M	M	M	M	M	D	D	M		D	L	M	D	T	T	TL			T	T	T	T
BB*	25	M	S	C	M		M	M	S	M	D	D	D	M		D	M	M	D	T	T	TL			T	T	T	T
	26	M	S	C	M		M	M	S	M	D	D	D	M		D	M	M	D	T	T	TL			T	T	T	T
	27	M	S	C	M		M	M	S	M	D	D	D	M		D	M	M	D	T	T	TL			T	T	T	T
	28	M	S	C	M		M	M	S	M	D	D	D	M		D	M	M	D	T	T	TL			T	T	T	T
	42	M	S	C	M		M	M	S	M	D	D	D	M		D	D	M	D	T	T	TL			T	T	T	T
	43	M	S	C	M		M	M	S	M	D	D	D	M		D	D	M	D	T	T	TL			T	T	T	T
	44	M	S	C	M		M	M	S	M	D	D	D	M		D	D	M	D	T	T	TL			T	T	T	T
	45	M	S	C	M		M	M	S	M	D	D	D	M		D	D	M	D	T	T	TL			T	T	T	T
CC	5	C	M	C	M		M	C	C	C	L	L	L	L		L	L	L	L	L	TL	L			L	L	L	L
	6	C	M	C	M		M	C	C	C	L	L	L	L		L	L	L	L	L	TL	L			L	L	L	L
	8	C	M	C	M		M	C	C	C	L	L	L	L		L	L	L	L	L	TL	L			L	L	L	L
CC*	20	C	M	C	M		M	M	C	C	L	M	L	L		L	M	L	M	L	TL	L			L	L	L	L
	21	C	M	C	M		M	M	C	C	L	M	L	L		L	M	L	M	L	TL	L			L	L	L	L
	22	C	M	C	M		M	M	C	C	L	M	L	L		L	M	L	M	L	TL	L			L	L	L	L
	23	C	M	C	M		M	M	C	C	L	M	L	L		L	M	L	M	L	TL	L			L	L	L	L
	24	C	M	C	M		M	M	C	C	L	M	L	L		L	M	L	M	L	TL	L			L	L	L	L
	25	C	M	C	M		M	M	C	C	L	M	L	L		L	M	L	M	L	TL	L			L	L	L	L
DD	4	C	C	VC	M		M	M	C	S	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	11	C	C	VC	M		M	M	C	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	12	C	C	VC	M		M	M	C	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	13	C	C	VC	M		M	M	C	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	14	C	C	VC	M		M	M	C	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	15	C	C	VC	M		M	M	C	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
DD*	32	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	33	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	34	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	35	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	36	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	37	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T
	38	C	C	VC	M		M	M	M	M	M	M	L	L		L	M	L	M	L	L	L			L	L	L	T

* Sand Blasted

ROW No. 4

Mark	Sheet No.	Texture						
DESIGNATION		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell
DD*	41	C	C	VC	M		C	M
	42	C	C	VC	M		C	M
	43	C	C	VC	M		C	M
EE†	4	S	S	S	S		C	S
	5	S	S	S	S		C	S
	6	S	S	S	S		C	S
EE*†	19	S	S	S	S		M	S
	20	S	S	S	S		M	S
	21	S	S	S	S		M	S
	22	S	S	S	S		M	S
	23	S	S	S	S		M	S
	24	S	S	S	S		M	S
HH	4	S	S	VS	M		M	S
	5	S	S	VS	M		M	S
	6	S	S	VS	M		M	S
	7	S	S	VS	M		M	S
	8	S	S	VS	M		M	S
	9	S	S	VS	M		M	S
HH*	27	S	S	VS	M		M	S
	28	S	S	VS	M		M	S
	29	S	S	VS	M		M	S
	30	S	S	VS	M		M	S
	31	S	S	VS	M		M	S
	32	S	S	VS	M		M	S
	33	S	S	VS	M		M	S
II	4	S	VS	VS	S		M	VS
	5	S	VS	VS	S		M	VS
	6	S	VS	VS	S		M	VS
	7	S	VS	VS	S		M	VS
	8	S	VS	VS	S		M	VS
II*	30	S	VS	VS	S		M	VS
	31	S	VS	VS	S		M	VS
	32	S	VS	VS	S		M	VS
	33	S	VS	VS	S		M	VS
	34	S	VS	VS	S		M	VS
	35	S	VS	VS	S		M	VS
	36	S	VS	VS	S		M	VS
	37	S	VS	VS	S		M	VS
KK	9	S	VS	M	S		M	S
	10	S	VS	M	S		M	S
	11	S	VS	M	S		M	S
	12	S	VS	M	S		M	S
	13	S	VS	M	S		M	S
	14	S	VS	M	S		M	S
	15	S	VS	M	S		M	S
KK*	35	S	VS	M	S		M	VS
	36	S	VS	M	S		M	VS
	37	S	VS	M	S		M	VS
	38	S	VS	M	S		M	VS
	39	S	VS	M	S		M	VS
	40	S	VS	M	S		M	VS

* Sand Blasted

† Open Annealed

CONDITION OF RUST

Texture	Color	Adherence
VS – Very Smooth	L – Light	T – Tight
S – Smooth	M – Medium	L – Loose
M – Medium	D – Dark	
C – Coarse		
VC – Very Coarse		

— INSPECTION COMMITTEE —

J. H. Gibboney, Chairman – Norfolk & Western Ry. Co.
J. A. Aupperle — American Rolling Mill Co
D. M. Buck — American Sheet & Tin Plate Co.
W. A. Cooper — Alan Wood Iron & Steel Co.
W. R. Fleming — The Andrews Steel Co.
D. J. Mc. Adam, Jr. — U. S. Navy, Bureau Steam Engineering
M. E. Mc. Donnell — Pennsylvania Railroad Co.
H. E. Smith — New York Central Railroad Co.
F. B. Wheaton — U. S. Army, Quartermaster's Corps.

NOTES:

— J. A. AUPPERLE —

Note: None.

— D. M. BUCK —

Note: None.

Table III.—Results of Inspection of Corrosion Test Sheets, at Annapolis, Md., October 13, 1920.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
ANNAPOLIS, MARYLAND

EXPOSED OCTOBER 17, 1916

CONDITION OF RUST

Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming	Adherence 5 Gibboney	Adherence 6 McAdam	Adherence 7 McDonnell	Adherence 8 Smith	Adherence 9 Wheaton
M		C	M	C	C	L	L	L	L		M	L	M	M	L	L	L			L	L	L	T
M		C	M	C	C	L	L	L	L		M	L	M	M	L	L	L			L	L	L	T
M		C	M	C	C	L	L	L	L		M	L	M	M	L	L	L			L	L	L	T
S		C	S	M	M	M	M	M	M		M	L	M	M	T	T	T			L	T	L	T
S		C	S	M	M	M	M	M	M		M	L	M	M	T	T	T			L	T	L	T
S		C	S	M	M	M	M	M	M		M	L	M	M	T	T	T			L	T	L	T
S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T

ROW No. 5

Mark	Sheet No.	Texture 1 Aupperle	Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming	Adherence 5 Gibboney	Adherence 6 McAdam	Adherence 7 McDonnell	Adherence 8 Smith	Adherence 9 Wheaton
XX*	11	VS	VS	M	S		C	VS	S	VS	D	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
	12	VS	VS	M	S		C	VS	S	VS	D	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
MM†	4	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	5	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	6	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	7	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	8	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	9	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	10	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	11	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	12	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	13	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	14	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
SS	4	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	5	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	6	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	7	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	8	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	9	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	10	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	11	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	12	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	13	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	14	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
TT	4	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	5	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	6	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	7	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	8	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	9	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	10	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	11	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	12	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	13	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	14	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
UU	4	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	5	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	6	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	7	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	8	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	9	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	10	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	11	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	12	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	13	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	14	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
VV	4	M	M	M	M		C	M	C	C	M	M	M	M		M	M	L	M	L	TL	TL			L	L	L	T
	5	M	M	M	M		C	M	C	C	M	M	M	M		M	M	L	M	L	TL	TL			L	L	L	T
	6	M	M	M	M		C	M	C	C	M	M	M	M		M	M	L	M	L	TL	TL			L	L	L	T

* Sand Blasted.
† Open Annealed.

ROW No. 6

Mark	Sheet No.	Texture 1 Aupperle	Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming	Adherence 5 Gibboney	Adherence 6 McAdam	Adherence 7 McDonnell	Adherence 8 Smith	Adherence 9 Wheaton
YY	7	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	8	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	9	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	10	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	11	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	12	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	13	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	14	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
XX	4	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	5	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	6	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	7	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	8	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	9	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	10	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	11	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	12	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	13	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	14	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
ZZ	1	C	C	VC	M		C	M	M	C	L	L	M	L		M	M	M	M	L	L	L			L	L	L	T
	2	C	C	VC	M		C	M	M	C	L	L	M	L		M	M	M	M	L	L	L			L	L	L	T
	4	C	C	VC	M		C	M	M	C	L	L	M	L		D	M	M	M	L	L	L			L	L	L	T
	307	S	S	S	S		M	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	L	T
	301	S	S	VS	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	302	S	S	VS	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	303	S	S	VS	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	201	S	S	S	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	202	S	S	S	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	204	S	VS	S	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	306	S	VS	VS	M		M	S	M	S	D	D	D	L		D	D	M	D	T	T	T			T	T	T	T
	902	S	S	VS	S		M	S	M	M	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	906	S	S	VS	S		S	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	710	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	711	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	102	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	102	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	417	S	M	M	M		M	S	M	M	D	M	M	M		D	D	M	D	T	T	TL			T	T	T	T
	418	S	M	M	M		M	S	M	M	D	M	M	M		D	D	M	D	T	T	TL			T	T	T	T
	419	S	M	M	M		M	S	M	M	D	M	M	M		D	D	M	D	T	T	TL			T	T	T	T
QQ	4	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	5	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	6	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	7	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	8	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	9	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	10	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	11	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	12	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T

ROW No. 7

Mark	Sheet No.	Texture 1 Aupperle	Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming
OO*	28	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	29	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	30	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	31	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	32	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	33	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	34	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
	35	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L	
A	4	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	5	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	6	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	7	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	8	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	9	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	10	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	11	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	12	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL	
	13	M	C	M	C		M	M	M		M	M	D	L		M	D	M		T	L	TL	
	14	M	C	M	C		M	M	M		M	M	D	L		M	D	M		T	L	TL	
	15	M	C	M	C		M	M	M		M	M	D	L		M	D	M		T	L	TL	
B	4	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL	
	6	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL	
	7	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL	
	8	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL	
	16	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL	
	25	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL	
	26	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL	
	27	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL	
	28	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL	
C	4	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	5	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	13	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	16	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	17	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	22	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	24	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	25	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
	26	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL	
D	8	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L	
	9	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L	
	12	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L	
	14	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L	
E	4	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	5	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	6	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	7	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	8	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	9	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	10	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	
	11	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T	

* Exposed 11-10-19

Buck —

: None.

— W. A. Cooper —

Sheet YY-2 — Scabs on Surface of Sheet. The Sheets all looked to be in good Order. The Top Surfaces were Smooth, having a Glass or Screen on them, and it was Difficult to Distinguish the Different Grades in "Texture" and "Adherence". The Under Surfaces of the Sheets had Granular Rust on them, and much of it was very Loose.

— W. R. Fleming —

Did not make Record of Adherence, because there was no Perceptible Difference in Sheets. In Fact most of the Sheets Showed no Marked Difference in Texture.

— J. H. Gibboney —

Did not Make this Inspection.

— D. J. McAdam —

Note.— Mr. E. T. Petrick of the Engineering Experiment Station, Represented Mr. McAdam at this Inspection.

TABLE III.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT ANNAPOLIS, MD., OCTOBER 13, 1920.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
ANNAPOLIS, MARYLAND

EXPOSED OCTOBER 17, 1916

CONDITION OF RUST

Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming	Adherence 5 Gibboney	Adherence 6 McAdam	Adherence 7 McDonnell	Adherence 8 Smith	Adherence 9 Wheaton
C	VC	M		C	M	C	C	L	L	L	L		M	L	M	M	L	L	L			L	L	L	T
C	VC	M		C	M	C	C	L	L	L	L		M	L	M	M	L	L	L			L	L	L	T
C	VC	M		C	M	C	C	L	L	L	L		M	L	M	M	L	L	L			L	L	L	T
S	S	S		C	S	M	M	M	M	M	M		M	L	M	M	T	T	T			L	T	L	T
S	S	S		C	S	M	M	M	M	M	M		M	L	M	M	T	T	T			L	T	L	T
S	S	S		C	S	M	M	M	M	M	M		M	L	M	M	T	T	T			L	T	L	T
S	S	S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S	S	S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S	S	S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S	S	S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S	S	S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S	S	S		M	S	S	S	M	D	M	M		M	M	D	M	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
S	VS	M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
S	VS	M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
S	VS	M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
S	VS	M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
S	VS	M		M	S	M	S	M	D	D	D		D	M	D	D	T	T	T			T	T	L	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
S	VS	M		M	S	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	VS	S		M	VS	S	VS	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	S	M	S	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
VS	M	S		M	VS	S	VS	M	D	M	D		D	D	D	D	T	T	TL			T	T	T	T

ROW No. 5

Designation Mark	Designation Sheet No.	Texture 1 Aupperle	Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming	Adherence 5 Gibboney	Adherence 6 McAdam	Adherence 7 McDonnell	Adherence 8 Smith	Adherence 9 Wheaton
XX*	41	VS	VS	M	S		C	VS	S	VS	D	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
	42	VS	VS	M	S		C	VS	S	VS	D	D	M	D		D	D	D	D	T	T	TL			T	T	T	T
MM†	4	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	5	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	6	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	7	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	8	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	9	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	10	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	11	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	12	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	13	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
	14	S	M	S	M		C	M	M	S	M	D	M	M		D	M	D	M	T	T	T			T	T	L	T
BB	4	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	5	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	6	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	7	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	8	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	9	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	10	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	11	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	12	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	13	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
	14	C	VC	C	M		C	C	VC	C	L	L	L	M		L	L	L	L	L	L	L			L	L	L	L
TT	4	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	5	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	6	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	7	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	8	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	9	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	10	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	11	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	12	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	13	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
	14	S	S	M	S		M	M	M	M	D	D	D	D		D	M	M	D	T	T	L			T	L	L	T
UU	4	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	5	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	6	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	7	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	8	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	9	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	10	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	11	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	12	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	13	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
	14	M	M	M	M		C	M	C	C	M	M	M	L		M	M	L	M	T	T	TL			L	L	T	T
VV	4	M	M	M	M		C	M	C	C	M	M	M	M		M	M	L	M	L	TL	TL			L	L	L	T
	5	M	M	M	M		C	M	C	C	M	M	M	M		M	M	L	M	L	TL	TL			L	L	L	T
	6	M	M	M	M		C	M	C	C	M	M	M	M		M	M	L	M	L	TL	TL			L	L	L	T

ROW No. 6

Designation Mark	Designation Sheet No.	Texture 1 Aupperle	Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper	Adherence 4 Fleming	Adherence 5 Gibboney	Adherence 6 McAdam	Adherence 7 McDonnell	Adherence 8 Smith	Adherence 9 Wheaton
YY	7	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	8	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	9	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	10	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	11	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	12	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	13	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
	14	C	M	M	M		C	M	C	C	L	M	M	L		L	M	L	M	L	TL	TL			L	L	L	T
XX	4	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	5	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	6	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	7	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	8	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	9	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	10	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	11	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	12	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	13	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
	14	C	VC	VC	M		C	VC	C	C	L	L	M	L		L	L	L	L	L	L	L			L	L	L	T
ZZ	1	C	C	VC	M		C	M	M	C	L	L	M	L		M	M	M	M	L	L	L			L	L	L	T
	2	C	C	VC	M		C	M	M	C	L	L	M	L		M	M	M	M	L	L	L			L	L	L	T
	4	C	C	VC	M		C	M	M	C	L	L	M	L		D	M	M	M	L	L	L			L	L	L	T
	307	S	S	S	S		M	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	L	T
	301	S	S	VS	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	302	S	S	VS	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	303	S	S	VS	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	201	S	S	S	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	202	S	S	S	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	204	S	VS	S	M		M	S	M	M	D	D	D	L		D	D	M	D	T	T	T			T	T	L	T
	806	S	VS	VS	M		M	S	M	S	D	D	D	L		D	D	M	D	T	T	T			T	T	T	T
	902	S	S	VS	S		M	S	M	M	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	906	S	S	VS	S		S	S	M	S	D	D	D	D		D	D	M	D	T	T	T			T	T	T	T
	710	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	711	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	102	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	103	S	S	VS	M		M	S	M	M	D	D	D	M		D	D	M	D	T	T	T			T	T	T	T
	417	S	M	M	M		M	S	M	M	D	M	M	M		D	D	M	D	T	T	TL			T	T	T	T
	418	S	M	M	M		M	S	M	M	D	M	M	M		D	D	M	D	T	T	TL			T	T	T	T
	419	S	M	M	M		M	S	M	M	D	M	M	M		D	D	M	D	T	T	TL			T	T	T	T
OO	4	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	5	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	6	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	7	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	8	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	9	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	10	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	11	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T
	12	M	C	M	M		M	M	M	C	M	M	M	M		D	D	M	D	T	TL	TL			L	L	L	T

ROW No. 7

Designation Mark	Designation Sheet No.	Texture 1 Aupperle	Texture 2 Buck	Texture 3 Cooper	Texture 4 Fleming	Texture 5 Gibboney	Texture 6 McAdam	Texture 7 McDonnell	Texture 8 Smith	Texture 9 Wheaton	Color 1 Aupperle	Color 2 Buck	Color 3 Cooper	Color 4 Fleming	Color 5 Gibboney	Color 6 McAdam	Color 7 McDonnell	Color 8 Smith	Color 9 Wheaton	Adherence 1 Aupperle	Adherence 2 Buck	Adherence 3 Cooper
CCC§	28	C	C	C	C		C	M	C	VC	L	L	M	L		L	M	L	M	L	L	L
	29	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
	30	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
	31	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
	32	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
	33	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
	34	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
	35	C	C	C	C		C	M	C	C	L	L	M	L		L	M	L	M	L	L	L
A	4	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	5	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	6	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	7	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	8	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	9	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	10	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	11	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	12	M	C	M	C		M	M	M	C	M	M	D	L		M	D	M	D	T	L	TL
	13	M	C	M	C		M	M	M		M	M	D	L		M	D	M		T	L	TL
	14	M	C	M	C		M	M	M		M	M	D	L		M	D	M		T	L	TL
	15	M	C	M	C		M	M	M		M	M	D	L		M	D	M		T	L	TL
B	5	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL
	6	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL
	7	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL
	8	M	M	M	M		S	M	M	C	M	M	D	D		M	M	M	D	T	T	TL
	24	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL
	25	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL
	26	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL
	27	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL
	28	M	M	M	M		S	M	M	C	M	M	D	D		M	D	M	D	T	T	TL
C	4	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	5	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	15	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	16	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	17	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	23	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	24	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	25	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
	26	C	C	M	C		M	M	M	C	L	L	L	L		L	L	L	L	L	L	TL
D	8	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L
	9	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L
	12	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L
	14	C	C	C	C		C	M	C	C	L	L	L	L		L	L	L	L	L	L	L
E	4	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	5	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	6	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	7	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	8	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	9	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	10	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T
	11	S	M	S	S		M	S	C	M	M	M	D	D		M	D	L	M	T	L	T

* Sand Blasted.
† Open Annealed.
§ Exposed 11-20-16.

— D. M. BUCK —

Note: None.

— W. A. COOPER —

Sheet YY-2 — Scabs on Surface of Sheet. The Sheets all looked to be in good Order. The Top Surfaces were Smooth, having a Glass or Screen on them, and it was Difficult to Distinguish the Different Grades in "Texture" and "Adherence". The Under Surfaces of the Sheets had Granular Rust on them, and much of it was very Loose.

— W. R. FLEMING —

Did not make Record of Adherence, because there was no Perceptible Difference in Sheets. In Fact most of the Sheets Showed no Marked Difference in Texture.

— J. H. GIBBONEY —

Did not Make this Inspection.

— D. J. McADAM —

Note.— Mr. E. T. Petrick of the Engineering Experiment Station, Represented Mr. McAdam at this Inspection.

Weather *Fair*

Adherence								
1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	T
T	L	TL			T	L	L	
T	L	TL			T	L	L	
T	L	TL			T	L	L	
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
T	T	TL			T	T	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	TL			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
L	L	L			L	L	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T
T	L	T			L	T	L	T

ROW No. 8

Designation		Condition of Rust: Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
H	4	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	5	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	6	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	7	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	8	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	9	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	10	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	11	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	12	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	13	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	14	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	15	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
	16	S	S	M	M		C	S	M	C	D	D	D	M		M	D	M	M	T	T	T			T	T	L	T
I	4	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	5	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	6	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	7	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	8	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	9	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	10	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	11	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	12	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	13	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	14	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	15	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	16	VS	VS	S	S		C	S	M	M	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
K	4	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	5	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	6	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	7	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	8	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	9	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	10	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	11	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	12	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	13	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	14	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	15	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
	16	S	VS	S	M		M	VS	M	S	D	D	D	D		M	D	M	M	T	T	T			T	T	L	T
M	4	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	5	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	6	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	7	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	8	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	9	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	10	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	11	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	12	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	13	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T
	14	M	M	M	M		C	M	M	M	M	D	M	D		M	M	M	M	T	T	T			L	T	L	T

ROW No. 9

Designation		Condition of Rust: Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
S	4	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	5	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	6	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	7	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	8	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	9	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	10	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	11	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	12	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	13	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
	14	VC	VC	VC	C		C	C	C	C	L	L	C	L		L	L	L	L	L	L	L			L	L	L	T
T	4	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	5	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	6	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	7	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	8	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	9	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	10	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	11	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	12	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	13	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
	14	S	S	C	S		C	M	M	M	D	D	M	D		M	D	M	D	T	T	TL			T	L	L	T
U	4	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	5	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	6	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	7	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	8	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	9	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	10	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	11	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	12	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	13	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	14	C	M	M	M		C	M	C	M	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
V	4	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	5	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	6	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	7	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	8	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	9	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	10	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	11	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	12	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	13	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
	14	C	M	M	M		C	M	C	C	M	M	M	M		L	M	L	M	T	L	TL			L	L	L	T
V*	1	C	C	M	M		C	M	C	C	M	D	L	M		L	L	L	M	L	L	TL			L	L	L	T
	2	C	C	M	M		C	M	C	C	M	D	L	M		L	L	L	M	L	L	TL			L	L	L	T
	3	C	C	M	M		C	M	C	C	M	D	L	M		L	L	L	M	L	L	TL			L	L	L	T

ROW No. 10

Designation		Condition of Rust: Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
X	4	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	5	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	6	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	7	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	8	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	9	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	10	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	11	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	12	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	13	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	14	C	C	C	C		C	C	C	VC	L	L	M	L		L	L	L	M	L	L	L			L	L	L	T
O	4	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	5	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	6	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	7	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	8	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	9	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	10	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	11	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
	12	S	VC	C	M		C	M	C	VC	M	L	D	M		M	M	M	D	T	L	L			L	L	L	L
Z	101	S	S	M	M		M	S	M	M	D	D	D	D		D	M	D	D	T	T	TL			T	T	T	T
	102	S	S	M	M		M	S	M	M	D	D	D	D		D	M	D	D	T	T	TL			T	T	T	T
	103	S	S	M	M		M	S	M	M	D	D	D	D		D	M	D	D	T	T	TL			T	T	T	T
	202	S	S	S	M		M	S	M	M	D	D	D	D		D	M	D	D	T	T	T			T	T	T	T
	204	S	S	S	M		M	S	M	M	D	D	D	D		D	M	D	D	T	T	T			T	T	T	T
	206	S	S	S	M		M	S	M	M	D	D	D	D		D	M	D	D	T	T	T			T	T	T	T
	301	S	VS	S	M		M	S	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	303	S	VS	S	M		M	S	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	305	S	VS	S	M		M	S	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	T	T
	417	C	C	C	C		C	C	C	C	L	L	L	M		M	L	M	M	L	L	L			T	L	L	T
	418	C	C	C	C		C	C	C	C	L	L	L	M		M	L	M	M	L	L	L			T	L	L	T
	419	C	C	C	C		C	C	C	C	L	L	L	M		M	L	M	M	L	L	L			T	L	L	T
	501	VS	S	VS	M		M	VS	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	502	VS	S	VS	M		M	VS	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	504	VS	S	VS	M		M	VS	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	602	VS	S	VS	M		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	603	VS	S	VS	M		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	604	VS	S	VS	M		M	VS	M	S	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	702	VS	S	VS	M		M	VS	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	706	VS	S	VS	M		M	VS	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
	707	VS	S	VS	M		M	VS	M	M	D	D	D	D		D	D	D	D	T	T	T			T	T	L	T
OOO*	30	M	C	C	C		C	C	C	C	M	L	L	L		L	L	L	M	T	L	L			L	L	L	T
YY†	1	C	VC	VC	C		C	C	C	VC	M	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	2	C	VC	VC	C		C	C	C	VC	M	L	M	L		L	L	L	M	L	L	L			L	L	L	T
	3	C	VC	VC	C		C	C	C	VC	M	L	M	L		L	L	L	M	L	L	L			L	L	L	T

* Exposed 8-1-1

* Exposed 11-29-16

† Exposed 8-1-17

— M. E. McDONNELL —

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at this

Sheets UU, 1-3 incl. Adherence Approaching Tight.
" VV, 1-3 " " " "
" CCC, 25-27 " " " "
" V, 1-3 " " " "
" TT, 4-14 " " " "
" UU, 4-14 " " " "
" T, 4-14 " " "

— H. E. SMITH —

Note: None.

— F. B. WHEATON —

Sheet E, 11 – Corner Bent down.
" O. 4 – Bent Corner.

James H. Gibboney

Chairman Inspection Committee

Date of Inspection April 4, 1921.

ROW No. 1

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	11	C	VC		VC			C	C		M	L		L			L	M		L	L		L			L	L	
	12	C	VC		VC			C	C		M	L		L			L	M		L	L		L			L	L	
	13	C	VC		VC			C	C		M	L		L			L	M		L	L		L			L	L	
BB	1	M	S		S			S	S		D	D		D			D	D		T	T		T			T	T	
	[illegible]	M	S		S			S	S		D	D		D			D	D		T	T		T			T	T	
	[illegible]	M	S		S			S	S		D	D		D			D	D		T	T		T			T	T	
CC	[illegible]	M	M		C			M	C		M	L		L			L	L		T	L		L			T	L	
	9	M	M		C			M	C		M	L		L			L	L		T	L		L			T	L	
	10	M	M		C			M	C		M	L		L			L	L		T	L		L			T	L	
DD	18	M	M		C			M	M		M	L		L			L	M		T	L		L			L	L	
	19	M	M		C			M	M		M	L		L			L	M		T	L		L			L	L	
	20	M	M		C			M	M		M	L		L			L	M		T	L		L			L	L	
EE*	7	S	S		M			S	S		D	D		D			D	D		T	T		T			T	T	
	8	S	S		M			S	S		D	D		D			M	D		T	T		T			T	T	
	9	S	S		M			S	S		D	D		D			M	D		T	T		T			T	T	
HH	10	S	S		S			S	M		D	D		D			M	M		T	T		T			T	T	
	11	S	S		S			S	M		D	D		D			M	M		T	T		T			T	T	
	12	S	S		S			S	[illegible]		D	D		D			M	M		T	T		T			T	T	
II	10	VS	VS		S			VS	VS		D	D		D			D	D		T	T		T			T	T	
	11	VS	VS		S			VS	VS		D	D		D			D	D		T	T		T			T	T	
	12	VS	VS		S			VS	VS		D	D		D			D	D		T	T		T			T	T	
KK	[illegible]	S	VS		S			S	S		M	D		D			D	D		T	T		T			T	T	
	[illegible]	S	VS		S			S	S		M	D		D			D	D		T	T		T			T	T	
	18	S	VS		S			S	S		M	D		D			D	D		T	T		T			T	T	
MM*	15	S	M		M			M	M		M	D		D			D	M		T	T		T			T	L	
	16	S	M		M			M	M		M	D		D			D	M		T	T		T			T	L	
	17	S	M		M			M	M		M	D		D			D	M		T	T		T			T	L	
NN	15	C	VC		VC			C	C		L	L		L			L	L		T	L		L			L	L	
	16	C	VC		VC			C	C		L	L		L			L	L		T	L		L			L	L	
	17	C	VC		VC			C	C		L	L		L			L	L		T	L		L			L	L	
TT	15	S	S		S			M	M		D	D		D			D	M		T	T		T			T	L	
	16	S	S		S			M	M		D	D		D			D	M		T	T		T			T	L	
	17	S	S		S			M	M		D	D		D			D	M		T	T		T			T	L	
UU	15	M	S		M			M	M		M	D		D			D	M		T	T		T			T	L	
	16	M	S		M			M	M		M	D		D			D	M		T	T		T			T	L	
	17	M	S		M			M	M		M	D		D			D	M		T	T		T			T	L	
VV	20	M	S		M			M	M		M	D		D			D	M		T	T		T			T	L	
	21	M	S		M			M	M		M	D		D			D	M		T	T		T			T	L	
	22	M	S		M			M	M		M	D		D			D	M		T	T		T			T	L	
XX	15	C	C		C			C	C		M	M		M			M	L		T	L		L			L	L	
	16	C	C		C			C	C		M	M		M			M	L		T	L		L			L	L	
	17	C	C		C			C	C		M	M		M			M	L		T	L		L			L	L	
OO	13	M	C		C			M	M		M	M		M			D	M		T	L		L			L	L	
	14	M	C		C			M	M		M	M		M			D	M		T	L		L			L	L	
	15	M	C		C			M	M		M	M		M			D	M		T	L		L			L	L	
YYY	13	M	C		C			C	M		M	M		M			M	M		T	L		L			L	L	
	14	M	C		C			C	M		M	M		M			M	M		T	L		L			L	L	
	15	M	C		C			C	M		M	M		M			M	M		T	L		L			L	L	

* Open Annealed

ROW No. 2

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
A	16	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	17	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	18	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
B	9	M	S		M			M	M		M	M		D			D	M		T	T		T			T	L	
	10	M	S		M			M	M		M	M		D			D	M		T	T		T			T	L	
	11	M	S		M			M	M		M	M		D			D	M		T	T		T			T	L	
C	6	M	M		C			M	M		M	M		L			M	M		T	L		L			T	L	
	7	M	M		C			M	M		M	M		L			M	M		T	L		L			T	L	
	8	M	M		C			M	M		M	M		L			M	M		T	L		L			T	L	
D	16	C	M		VC			M	C		M	M		L			L	L		T	L		L			L	L	
	19	C	M		VC			M	C		M	M		L			L	L		T	L		L			L	L	
	22	C	M		VC			M	C		M	M		L			L	L		T	L		L			L	L	
E	13	S	S		M			S	S		D	D		D			D	D		T	T		T			T	L	
	14	S	S		M			S	S		D	D		D			D	D		T	T		T			T	L	
	15	S	S		M			S	S		D	D		D			D	D		T	T		T			T	L	
H	19	S	S		M			S	M		D	D		D			D	D		T	T		T			T	L	
	20	S	S		M			S	M		D	D		D			D	D		T	T		T			T	L	
	22	S	S		M			S	M		D	D		D			D	D		T	T		T			T	L	
I	19	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	20	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	21	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
K	17	S	VS		M			VS	M		D	D		D			D	D		T	T		T			T	L	
	18	S	VS		M			VS	M		D	D		D			D	D		T	T		T			T	L	
	19	S	VS		M			VS	M		D	D		D			D	D		T	T		T			T	L	
M	15	S	M		M			S	M		D	D		D			M	D		T	T		T			T	L	
	16	S	M		M			S	M		D	D		D			D	D		T	T		T			T	L	
	17	S	M		M			M	M		D	D		D			D	D		T	T		T			T	L	
N	15	C	VC		VC			C	VC		L	L		L			L	L		T	L		L			L	L	
	16	C	VC		VC			C	VC		L	L		L			L	L		T	L		L			L	L	
	17	C	VC		VC			C	VC		L	L		L			L	L		T	L		L			L	L	
T	15	S	S		S			S	S		D	D		D			D	M		T	T		T			T	T	
	16	S	S		S			S	S		D	D		D			D	M		T	T		T			T	T	
	17	S	S		S			S	S		D	D		D			D	M		T	T		T			T	T	
U	15	M	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	16	M	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	17	M	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
V	15	M	S		M			S	M		M	D		M			D	M		T	T		T			T	L	
	16	M	S		M			S	M		M	D		M			D	M		T	T		T			T	L	
	17	M	S		M			S	M		M	D		M			D	M		T	T		T			T	L	
X	15	C	C		C			C	C		M	L		L			M	M		L	L		L			L	L	
	16	C	C		C			C	C		M	L		L			M	M		L	L		L			L	L	
	17	C	C		C			C	C		M	L		L			M	M		L	L		L			L	L	
O	13	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	14	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	15	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
Z	4	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	5	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	100	S	S		S			M	S		D	D		D			M	D		T	T		T			T	T	

ROW No. 3

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Adherence 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
AA	14	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
	15	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
	16	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
	17	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
	18	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
	19	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
	20	M	C		VC			C	VC		M	M		L			L	L		L	L		L			L	L	
AA*	42	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	43	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	44	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	45	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	46	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	47	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	48	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	49	M	C		VC			C	C		M	M		L			L	M		L	L		L			L	L	
BB	7	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	15	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	16	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	17	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	18	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	19	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
BB*	29	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	30	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	31	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	32	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	46	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	47	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	48	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
	49	S	M		S			M	S		D	D		D			D	D		T	T		T			T	T	
CC	11	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	12	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	13	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	14	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
CC*	26	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	27	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	28	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	29	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
	30	C	C		C			C	C		L	L		L			L	L		L	L		L			L	L	
DD	5	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
	6	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
	7	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
	21	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
	22	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
	23	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
	24	C	C		C			M	C		L	M		L			L	L		L	L		L			L	L	
YY†	3	M	C		C			C	C		L	M		L			M	M		L	L		L			L	L	
	4	M	C		C			C	C		L	M		L			M	M		L	L		L			L	L	
	5	M	C		C			C	C		L	M		L			M	M		L	L		L			L	L	
Y†	4	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	

* Sand Blasted

† Exposed 9-13-17.

ROW No. 4

Mark	Sheet No.	Texture 1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	Color 1
DD*	39	C	C		VC			M	M		L
	40	C	C		VC			M	M		L
	44	C	C		VC			M	M		L
	45	C	C		VC			M	M		L
	46	C	C		VC			M	M		L
	50	C	C		VC			M	M		L
	51	C	C		VC			M	M		L
	52	C	C		VC			M	M		L
	53	C	C		VC			M	M		L
EE†	10	S	M		S			S	S		D
	11	S	M		S			S	S		D
	12	S	M		S			S	S		D
EE*†	25	S	M		S			S	S		D
	26	S	M		S			S	S		D
	27	S	M		S			S	S		D
	28	S	M		S			S	S		D
	29	S	M		S			S	S		D
	30	S	M		S			S	S		D
HH	13	S	S		M			S	S		D
	14	S	S		M			S	S		D
	15	S	S		M			S	S		D
	16	S	S		M			S	S		D
	17	S	S		M			S	S		D
	18	S	S		M			S	S		D
HH*	35	S	S		M			S	S		D
	36	S	S		M			S	S		D
	37	S	S		M			S	S		D
	38	S	S		M			S	S		D
	39	S	S		M			S	S		D
	40	S	S		M			S	S		D
	41	S	S		M			S	S		D
	42	S	S		M			S	S		D
II	13	VS	VS		M			VS	VS		D
	14	VS	VS		M			VS	VS		D
	15	VS	VS		M			VS	VS		D
	16	VS	VS		M			VS	VS		D
	17	VS	VS		M			VS	VS		D
	18	VS	VS		M			VS	VS		D
	19	VS	VS		M			VS	VS		D
II*	39	VS	VS		M			VS	VS		D
	40	VS	VS		M			VS	VS		D
	41	VS	VS		M			VS	VS		D
	42	VS	VS		M			VS	VS		D
	43	VS	VS		M			VS	VS		D
	44	VS	VS		M			VS	VS		D
	45	VS	VS		M			VS	VS		D
	46	VS	VS		M			VS	VS		D
	47	VS	VS		M			VS	VS		D

* Sand Blasted

† Open Annealed

CONDITION OF RUST

Texture	Color	Adherence
VS - Very Smooth	L - Light	T - Tight
S - Smooth	M - Medium	L - Loose
M - Medium	D - Dark	
C - Coarse		
VC - Very Coarse		

— INSPECTION COMMITTEE —

J. H. Gibboney, Chairman — Norfolk & Western Ry. Co.
J. A. Aupperle — American Rolling Mill Co.
D. M. Buck — American Sheet & Tin Plate Co.
W. A. Cooper — Alan Wood Iron & Steel Co.
W. R. Fleming — The Andrews Steel Co.
D. J. Mc Adam, Jr. — U. S. Navy, Bureau Steam Engineering.
M. E. Mc Donnell — Pennsylvania Railroad Co.
H. E. Smith — New York Central Railroad Co.
F. B. Wheaton — U. S. Army, Quartermaster's Corps.

NOTES: (GENERAL)

Sheets Marked with a Star (*) under "Condition of Rust" were not Considered for Detail Physical Inspection Due to Reported Failure.

The Following Sheets were Reported as Failures prior to this Inspection:

A – 16, 17 and 18.
O – 13, 14, 15, 16, 17, 18, 21, 22, 23 and 24.
Y – 4
Z – 421

The Followi
as Failures o
Z –
A –
X –

TABLE IV.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT FORT SHERIDAN, ILL., APRIL 4, 1921.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
FORT SHERIDAN, ILL.

EXPOSED APRIL 9, 1917

CONDITION OF RUST

Texture		Color									Adherence								
Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	

ROW No. 5

DESIGNATION		CONDITION OF RUST Texture									Color									Adherence								
		Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9
KK	19	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	20	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	21	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	22	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	23	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	24	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	25	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	26	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
KK*	43	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	44	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	45	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	46	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	47	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	48	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	49	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	50	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
MM†	18	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	19	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	20	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	21	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	22	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	23	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	24	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	25	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	26	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	27	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	28	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
[illegible]	18	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	19	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	20	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	22	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	23	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	24	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	25	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	26	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	27	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
TT	18	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	19	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	20	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	21	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	22	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	23	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	24	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	25	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	26	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	27	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	28	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
Y‡	6	M	C		C			C	M		M	M		M			D	M		T	L		L			L	L	
	5	M	C		C			VC	M		M	M		M			M	M		T	L		L			L	L	

* Sand Blasted.
† Open Annealed.
‡ Exposed 9-10-17

ROW No. 6

DESIGNATION		CONDITION OF RUST Texture									Color									Adherence								
		Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9
UU	18	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	19	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	20	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	22	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	23	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	24	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	25	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	26	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	27	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	28	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
YY	23	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	24	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	25	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	26	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	27	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	28	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	29	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	30	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	31	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	32	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	33	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	34	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	35	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	36	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	37	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	38	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
XX	18	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	19	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	20	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	21	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	22	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	23	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	24	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	25	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	26	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	27	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	28	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
ZZ	5	C	C		VC			C	M		L	L		L			L	M		L	L		L			L	L	
	7	C	C		VC			C	M		L	L		L			L	M		L	L		L			L	L	
	308	VS	S		M			S	S		D	D		D			D	D		T	T		T			T	T	
	309	VS	S		M			S	S		D	D		D			D	D		T	T		T			T	T	
	505	S	S		M			S	M		M	D		D			M	M		T	T		T			T	T	
	506	S	S		M			S	M		M	D		D			M	M		T	T		T			T	T	
	610	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	611	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	

ROW No. 7

DESIGNATION		CONDITION OF RUST Texture									Color									Adherence								
		Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9	Aupperle 1	Buck 2	Cooper 3	Fleming 4	Gibboney 5	McAdam 6	McDonnell 7	Smith 8	Wheaton 9
ZZ	106	M	S		S			S	S		D	D		D			D	D		T	T		T			T	T	
	205	S	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	206	S	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	620	M	M		M			M	M		M	M		M			M	M		T	L		T			T	L	
	622	M	M		M			M	M		M	M		M			M	M		T	L		T			T	L	
	712	S	VS		M			S	S		D	D		D			D	D		T	T		T			T	T	
	713	S	VS		M			S	S		D	D		D			D	D		T	T		T			T	T	
OO	16	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	17	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	18	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	19	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	20	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	21	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	22	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	23	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	24	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
CCC	16	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	17	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	18	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	19	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	20	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	21	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	22	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	23	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	24	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
A	19	■	■		■			■	■		■	■		■			■	■		■	■		■			■	■	
	20	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	21	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	22	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	23	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	24	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	25	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	26	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	27	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	28	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	29	■	■		■			■	■		■	■		■			■	■		■	■		■			■	■	
	30	■	■		■			■	■		■	■		■			■	■		■	■		■			■	■	
B	12	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	13	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	14	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	15	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	16	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	29	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	30	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	31	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	32	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	33	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
Z	710	VS	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	

Following Additional Sheets are Reported
ilures at this Inspection.
Z – 4 and 5
A – 19, 29 and 30
X – 25

W. A. Cooper
J. H. Gibboney
D. J. Mc.Adam, Jr.
F. B. Wheaton
} Did not make this Inspection.

Sheets Z-4 and 5 Failed. Several Small Holes.
" A-19, 29, 30 " . One Hole.
Sheet X-25 " . " " .

TABLE IV.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT FORT SHERIDAN, ILL., APRIL 4, 1921.

AMERICAN SOCIETY FOR TESTING MATERIALS

COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
FORT SHERIDAN, ILL.

EXPOSED APRIL 9, 1917

Texture		CONDITION OF RUST — Color									Adherence								
8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
M		L	M		L			L	L		L	L		L			T	L	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
S		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	
VS		D	D		D			D	D		T	T		T			T	T	

ROW No. 5

DESIGNATION		CONDITION OF RUST																										
		Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
KK	19	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	20	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	21	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	22	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	23	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	24	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	25	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
	26	S	VS		S			VS	S		D	D		D			D	M		T	T		T			T	T	
KK*	43	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	44	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	45	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	46	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	47	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	48	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	49	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
	50	S	VS		S			VS	VS		D	D		D			D	M		T	T		T			T	T	
MM†	18	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	19	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	20	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	21	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	22	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	23	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	24	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	25	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	26	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	27	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
	28	M	M		M			M	M		M	D		D			D	M		T	T		T			T	T	
[illegible]	18	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	19	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	20	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	22	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	23	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	24	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	25	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	26	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
	27	C	VC		VC			C	C		L	L		L			L	L		L	L		L			L	L	
TT	18	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	19	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	20	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	21	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	22	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	23	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	24	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	25	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	26	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	27	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
	28	S	S		M			S	M		M	D		D			D	M		T	T		T			T	L	
YY‡	6	M	C		C			C	M		M	M		M			D	M		T	L		L			L	L	
	5	M	C		C			VC	M		M	M		M			M	M		T	L		L			L	L	

ROW No. 6

DESIGNATION		CONDITION OF RUST																										
		Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
UU	18	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	19	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	20	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	22	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	23	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	24	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	25	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	26	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	27	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
	28	M	S		M			M	M		M	D		D			M	M		T	T		T			T	L	
YY	23	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	24	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	25	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	26	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	27	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	28	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	29	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	30	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	31	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	32	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	33	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	34	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	35	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	36	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	37	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
	38	M	S		C			M	M		M	D		M			M	M		T	T		L			T	L	
XX	18	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	19	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	20	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	21	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	22	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	23	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	24	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	25	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	26	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	27	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
	28	M	VC		VC			C	C		M	M		L			L	L		T	L		L			L	L	
ZZ	5	C	C		VC			C	M		L	L		L			L	M		L	L		L			L	L	
	7	C	C		VC			C	M		L	L		L			L	M		L	L		L			L	L	
	308	VS	S		M			S	S		D	D		D			D	D		T	T		T			T	T	
	309	VS	S		M			S	S		D	D		D			D	D		T	T		T			T	T	
	505	S	S		M			S	M		M	D		D			M	M		T	T		T			T	T	
	506	S	S		M			S	M		M	D		D			M	M		T	T		T			T	T	
	610	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	611	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	

ROW No. 7

DESIGNATION		CONDITION OF RUST																										
		Texture									Color									Adherence								
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
ZZ	106	M	S		S			S	S		D	D		D			D	D		T	T		T			T	T	
	205	S	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	206	S	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	420	M	M		M			M	M		M	M		M			M	M		T	L		T			T	L	
	422	M	M		M			M	M		M	M		M			M	M		T	L		T			T	L	
	712	S	VS		M			S	S		D	D		D			D	D		T	T		T			T	T	
	713	S	VS		M			S	S		D	D		D			D	D		T	T		T			T	T	
OO	16	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	17	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	18	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	19	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	20	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	21	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	22	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	23	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
	24	M	C		C			M	M		M	M		L			M	M		T	L		L			T	L	
OOO	16	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	17	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	18	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	19	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	20	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	21	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	22	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	23	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
	24	C	C		C			M	C		M	M		L			M	L		L	L		L			T	L	
A	19	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	20	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	21	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	22	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	23	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	24	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	25	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	26	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	27	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	28	C	VC		VC			C	C		M	M		L			L	M		L	L		L			L	L	
	29	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
	30	*	*		*			*	*		*	*		*			*	*		*	*		*			*	*	
B	12	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	13	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	14	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	15	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	16	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	29	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	30	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	31	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	32	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
	33	M	M		M			M	M		M	M		D			M	M		T	T		T			T	L	
E	710	VS	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	

* Sand Blasted

† Open Annealed

‡ Exposed 6-15-17

The Following Additional Sheets are Reported Failures at this Inspection.
Z - 4 and 5
A - 19, 29 and 30
X - 25

W. A. Cooper
J. H. Gibboney
D. J. Mc Adam, Jr.
F. B. Wheaton } *Did not make this Inspection.*

Sheets Z-4 and 5 Failed. Several Small Holes.
" A-19, 29, 30 " . One Hole.
Sheet X-25 " " " .

PLATE IV.
PROC. AM. SOC. TEST. MATS.
VOL. 21.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

Weather *Fair and Warm*

ROW No. 8

DESIGNATION		CONDITION OF RUST: Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
C	9	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	10	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	18	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	19	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	27	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	28	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	29	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	30	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
	31	C	M		M			M	M		M	M		M			L	L		T	L		T			L	L	
D	24	C	C		C			M	M		L	L		L			L	L		T	L		L			L	L	
	25	C	C		C			M	M		L	L		L			L	L		T	L		L			L	L	
	26	C	C		C			M	M		L	L		L			L	L		T	L		L			L	L	
E	16	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	17	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	18	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	19	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	20	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	21	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	22	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	23	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
	24	S	M		M			S	S		D	D		D			D	M		T	T		T			T	T	
H	23	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	24	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	25	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	26	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	29	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	33	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	35	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	36	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
I	22	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	23	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	24	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	25	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	26	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	27	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	28	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	29	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	30	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	31	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	32	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	33	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	34	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	35	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	36	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
	37	VS	VS		S			VS	S		D	D		D			D	D		T	T		T			T	T	
Z	605	S	VS		M			VS	M		D	D		D			D	D		T	T		T			T	T	
	606	S	VS		M			VS	M		D	D		D			D	D		T	T		T			T	T	
	709	S	VS		M			VS	M		D	D		D			D	D		T	T		T			T	T	

ROW No. 9

DESIGNATION		CONDITION OF RUST: Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
K	20	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	21	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	22	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	23	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	24	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	25	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	26	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	27	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	28	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	29	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	30	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	31	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
	32	S	VS		S			S	S		D	D		D			D	M		T	T		T			T	T	
M	18	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	19	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	20	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	21	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	22	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	23	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	24	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	25	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	26	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	27	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
	28	S	M		M			M	M		D	D		D			D	M		T	T		T			T	T	
S	18	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	19	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	20	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	21	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	22	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	23	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	24	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	25	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	26	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	27	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
	28	C	VC		VC			C	C		M	L		L			L	L		T	L		L			L	L	
T	18	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	19	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	20	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	21	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	22	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	23	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	24	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	25	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	26	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	27	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
	28	S	S		M			S	M		D	D		D			D	M		T	T		T			T	L	
U	18	S	M		C			M	M		D	D		M			D	M		T	T		T			T	L	
	19	S	M		C			M	M		D	D		M			D	M		T	T		T			T	L	
	20	S	M		C			M	M		D	D		M			D	M		T	T		T			T	L	
	21	S	M		C			M	M		D	D		M			D	M		T	T		T			T	L	

ROW No. 10

DESIGNATION		CONDITION OF RUST: Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 McAdam	7 McDonnell	8 Smith	9 Wheaton
U	22	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
	23	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
	24	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
	25	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
	26	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
	27	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
	28	M	M		M			M	M		M	D		M			M	M		T	T		T			T	L	
V	18	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	19	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	20	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	21	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	22	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	23	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	24	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	25	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	26	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	27	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
	28	M	M		M			S	M		M	D		M			D	M		T	T		T			T	L	
X	4	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	19	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	20	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	21	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	22	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	23	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	24	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	25	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	26	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	27	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
	28	C	VC		C			C	C		L	L		L			L	L		L	L		L			L	L	
O	16	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	17	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	18	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	19	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	20	M	C		C			C	VC		M	M		M			M	M		L	L		L			L	L	
	21	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	22	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	23	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	24	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
Z	140	VS	S		S			S	S		D	D		D			D	D		T	T		T			T	T	
	207	VS	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	208	VS	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	206	VS	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	209	VS	VS		S			S	S		D	D		D			D	D		T	T		T			T	T	
	420	C	C		C			C	C		L	M		L			L	M		L	L		L			L	L	
	421	●	●		●			●	●		●	●		●			●	●		●	●		●			●	●	
	505	S	VS		M			M	M		M	D		D			M	M		T	T		T			T	T	
	506	S	VS		M			M	M		M	D		D			M	M		T	T		T			T	T	

James H. Gibboney
Chairman Inspection Committee

Date of Inspection *April 5, 1921.*

ROW No. 1

DESIGNATION		CONDITION OF RUST																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
AA	21	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	22	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	23	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	24	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
		*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
BB	18	M	S	M	M			S	S		M	M	D				D	D		T	T	T				T	L	
	19	M	S	M	M			S	S		M	M	D				D	D		T	T	T				T	L	
	20	C	M	C	C			M	M		M	M	M				M	M		T	L	L				L	L	
	21	C	M	C	C			M	M		M	M	M				M	M		T	L	L				L	L	
CC	15	C	C	VC	C			C	M		M	M	M				M	M		L	L	L				L	L	
	16	C	C	VC	C			C	M		M	M	M				M	M		L	L	L				L	L	
	17	C	C	VC	C			C	M		M	M	M				M	M		L	L	L				L	L	
	18	C	C	VC	C			C	M		M	M	M				M	M		L	L	L				L	L	
DD	25	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	26	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	27	VC	VC	VC	VC			VC	C		L	M	L				L	L		L	L	L				L	L	
	28	VC	VC	VC	VC			VC	C		L	M	L				L	L		L	L	L				L	L	
EE*	13	S	S	S	S			S	VS		D	D	D				D	D		T	T	T				T	T	
	14	S	S	S	S			S	VS		D	D	D				D	D		T	T	T				T	T	
	15	S	S	S	S			S	VS		D	D	D				D	D		T	T	T				T	T	
	16	S	S	S	S			S	VS		D	D	D				D	D		T	T	T				T	T	
HH	19	S	S	VS	S			S	VS		D	D	D				D	D		T	T	T				T	T	
	20	S	S	VS	S			S	VS		D	D	D				D	D		T	T	T				T	T	
	21	S	S	VS	S			S	VS		D	D	D				D	D		T	T	T				T	T	
	22	S	S	VS	S			S	VS		D	D	D				D	D		T	T	T				T	T	
II	20	VS	VS	VS	VS			VS	VS		D	D	D				D	D		T	T	T				T	T	
	21	VS	VS	VS	VS			VS	VS		D	D	D				D	D		T	T	T				T	T	
	22	VS	VS	VS	VS			VS	VS		D	D	D				D	D		T	T	T				T	T	
	23	VS	VS	VS	VS			VS	VS		D	D	D				D	D		T	T	T				T	T	
KK	6	S	VS	VS	VS			VS	S		D	D	D				D	D		T	T	T				T	T	
	7	S	VS	VS	VS			VS	S		D	D	D				D	D		T	T	T				T	T	
	8	S	VS	VS	VS			VS	S		D	D	D				D	D		T	T	T				T	T	
	27	S	VS	VS	VS			VS	S		D	D	D				D	D		T	T	T				T	T	
MM*	29	M	M	C	C			M	M		M	M	M				M	M		T	L	L				L	L	
	30	M	M	C	C			M	M		M	M	M				M	M		T	L	L				L	L	
	31	M	M	C	C			M	M		M	M	M				M	M		T	L	L				L	L	
	32	M	M	C	C			M	M		M	M	M				M	M		T	L	L				L	L	
SS	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
		*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
TT	29	S	S	S	S			S	VS		L	D	D				D	D		T	T	T				T	T	
	30	S	S	S	S			S	VS		L	D	D				D	D		T	T	T				T	T	
	31	S	S	S	S			S	VS		L	D	D				D	[illegible]		T	T	T				T	T	
	32	S	S	S	S			S	VS		L	D	D				D	[illegible]		T	T	T				T	T	
UU	29	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
	30	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
	31	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
	32	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
VV	39	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
	40	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
	41	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
	42	S	S	M	S			S	S		D	D	M				D	D		T	T	T				T	T	
											*	*	*				*	*		*	*	*				*	*	
XX	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
OO	25	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	26	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	27	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	28	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
CCC	1	S	M	M	S			S	S		D	D	D				D	D		T	T	T				T	T	
	2	S	M	M	S			S	S		D	D	D				D	D		T	T	T				T	T	
	3	S	M	M	S			S	S		D	D	D				D	D		T	T	T				T	T	
	4	S	M	M	S			S	S		D	D	D				D	D		T	T	T				T	T	
ZZ	9	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	10	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	14	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	107	S	S	S	S			M	S		D	D	D				M	D		T	T	T				T	L	
	310	S	VS	VS	VS			S	S		D	D	D				D	D		T	T	T				T	L	
	311	S	VS	VS	VS			S	S		D	D	D				D	D		T	T	T				T	L	

[illegible]

ROW No. 2

DESIGNATION		CONDITION OF RUST																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
A	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	33	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	34	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
B	17	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	18	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	19	M	C	M	C			C	M		M	M	D				M	M		T	L	L				L	L	
	20	M	C	M	C			C	M		M	M	D				M	M		T	L	L				L	L	
C	11	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	12	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	13	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	14	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
D	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	34	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
E	25	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	26	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	27	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	28	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
H	39	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	40	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	41	S	M	S	M			S	M		D	D	D				D	D		T	T	T				T	L	
	42	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
I	38	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	39	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	40	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	41	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
K	33	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	34	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	35	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	36	S	S	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
M	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	S	M	M	M			M	M		D	D	D				M	M		T	T	L				L	L	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
S	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
T	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
U	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
V	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
X	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	31	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	32	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
O	25	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	26	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	27	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	28	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
Z	6	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	7	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	11	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	111	S	M	M	S			S	M		D	D	D				D	M		T	T	TL				T	L	
	112	S	M	M	S			S	M		D	D	D				D	M		T	T	TL				T	L	
	113	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	309	VS	VS	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	213	VS	VS	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	214	VS	VS	S	S			VS	S		D	D	D				D	D		T	T	T				T	T	
	310	VS	VS	VS	S			VS	S		D	D	D				D	D		T	T	T				T	T	

ROW No. 3

DESIGNATION		CONDITION OF RUST																										
Mark	Sheet No.	Texture									Color									Adherence								
		1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton	1 Aupperle	2 Buck	3 Cooper	4 Fleming	5 Gibboney	6 Mc Adam	7 Mc Donnell	8 Smith	9 Wheaton
AA	25	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	26	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	27	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	28	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	29	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	30	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
AA*	50	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	51	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	52	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	53	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	54	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	55	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
	56	*	*	*	*			*	*		*	*	*				*	*		*	*	*				*	*	
BB	22	C	C	VC	VC			C	C		L	M	L				M	L		L	L	L				L	L	
	23	C	C	VC	VC			C	C		L	M	L				M	L		L	L	L				L	L	
	24	C	C	VC	VC			C	C		L	M	L				M	L		L	L	L				T	L	
	40	M	M	C	C			M	M		M	D	D				D	M		T	T	TL				T	L	
	41	M	M	C	C			M	M		M	D	D				D	M		T	T	TL				T	L	
BB*	33	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	34	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	35	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	36	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	50	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	51	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	52	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
	53	M	M	C	M			M	M		M	M	M				M	M		T	L	TL				T	L	
CC	7	M	VC	VC	C			M	M		M	M	L				M	M		L	L	L				L	L	
	19	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
CC*	31	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
	32	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
	33	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
	34	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
	35	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
	36	C	VC	VC	C			C	C		M	M	L				L	L		L	L	L				L	L	
DD	8	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	9	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	10	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	29	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	30	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	31	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
DD*	47	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	48	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	49	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	54	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	55	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	56	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	57	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
	58	VC	VC	VC	VC			VC	VC		L	M	L				L	L		L	L	L				L	L	
EE†	17	S	S	S	M			S	S		D	D	D				D	D		T	L	T				T	T	
	18	S	S	S	M			S	S		D	D	D				D	D		T	L	T				T	T	
EE*†	31	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	T	
	32	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	T	
	33	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	T	
	34	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	T	
	35	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	T	
	36	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	T	
HH	23	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	24	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	25	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	26	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
HH*	43	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	44	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	45	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	46	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	47	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	48	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
	49	S	S	S	M			S	S		D	D	D				D	D		T	T	T				T	L	
II	24	VS	VS	VS	S			VS	VS		D	D	D				D	D		T	T	T				T	T	
	25	VS	VS	VS	S			VS	VS		D	D	D				D	D		T	T	T				T	T	
	27	VS	VS	VS	S			VS	VS		D	D	D				D	D		T	T	T				T	T	
	28	VS	VS	VS	S			VS	VS		D	D	D				D	D		T	T	T				T	T	
	29	VS	VS	VS	S			VS	VS		D	D	D				D	D		T	T	T				T	T	

* Sand Blasted.

† Open Annealed.

ROW No. 4

DESIGNATION		Texture			
Mark	Sheet No.	1 Aupperle	2 Buck	3 Cooper	4 Fleming
II**	48	VS	VS	VS	S
	49	VS	VS	VS	S
	50	VS	VS	VS	S
	51	VS	VS	VS	S
	52	VS	VS	VS	S
	53	VS	VS	VS	S
	54	VS	VS	VS	S
	55	VS	VS	VS	S
	56	VS	VS	VS	S
KK	28	S	VS	S	S
	29	S	VS	S	S
	30	S	VS	S	S
	31	S	VS	S	S
	32	S	VS	S	S
	33	S	VS	S	S
	34	S	VS	S	S
KK*	51	S	VS	S	S
	52	S	VS	S	S
	53	S	VS	S	S
	54	S	VS	S	S
	55	S	VS	S	S
	56	S	VS	S	S
	57	S	VS	S	S
	58	S	VS	S	S
MM†	33	C	C	C	C
	34	C	C	C	C
	35	C	C	C	C
	36	C	C	C	C
	37	C	C	C	C
	38	C	C	C	C
	39	C	C	C	C
	40	C	C	C	C
	41	C	C	C	C
	42	C	C	C	C
SS	33	*	*	*	*
	34	*	*	*	*
	35	*	*	*	*
	36	*	*	*	*
	37	*	*	*	*
	38	*	*	*	*
	39	*	*	*	*
	40	*	*	*	*
	41	*	*	*	*
	42	*	*	*	*
TT	33	M	S	M	M
	34	M	S	M	M
	35	M	S	M	M
	36	M	S	M	M
	37	M	S	M	M
	38	M	S	M	M
	39	M	S	M	M
	40	M	S	M	M
	41	M	S	M	M
	42	M	S	M	M
UU	33	M	S	M	M
	34	M	S	M	M
	35	M	S	M	M
	36	M	S	M	M
	37	M	S	M	M
	38	M	S	M	M
	39	M	S	M	M
	40	M	S	M	M
	41	M	S	M	M
	42	M	S	M	M
VV	43	M	S	M	M
	44	M	S	M	M
	45	M	S	M	M
	46	M	S	M	M
	47	M	S	M	M
	48	M	S	M	M
	49	M	S	M	M
	50	M	S	M	M
	51	M	S	M	M

* Sand Blasted.

† Open Annealed.

CONDITION OF RUST

Texture	Color	Adherence
VS — Very Smooth	L — Light	T — Tight
S — Smooth	M — Medium	L — Loose
M — Medium	D — Dark	
C — Coarse		
VC — Very Coarse		

— INSPECTION COMMITTEE —

J. H. Gibboney, Chairman	— Norfolk & Western Ry. Co.
J. A. Aupperlé	— American Rolling Mill Co.
D. M. Buck	— American Sheet & Tin Plate Co.
W. A. Cooper	— Alan Wood Iron & Steel Co.
W. R. Fleming	— The Andrews Steel Co.
D. J. McAdam, Jr.	— U.S. Navy, Bureau Steam Engineering.
M. E. Mc Donnell	— Pennsylvania Railroad Co.
H. E. Smith	— New York Central Railroad Co.
F. B. Wheaton	— U.S. Army, Quartermaster's Corps.

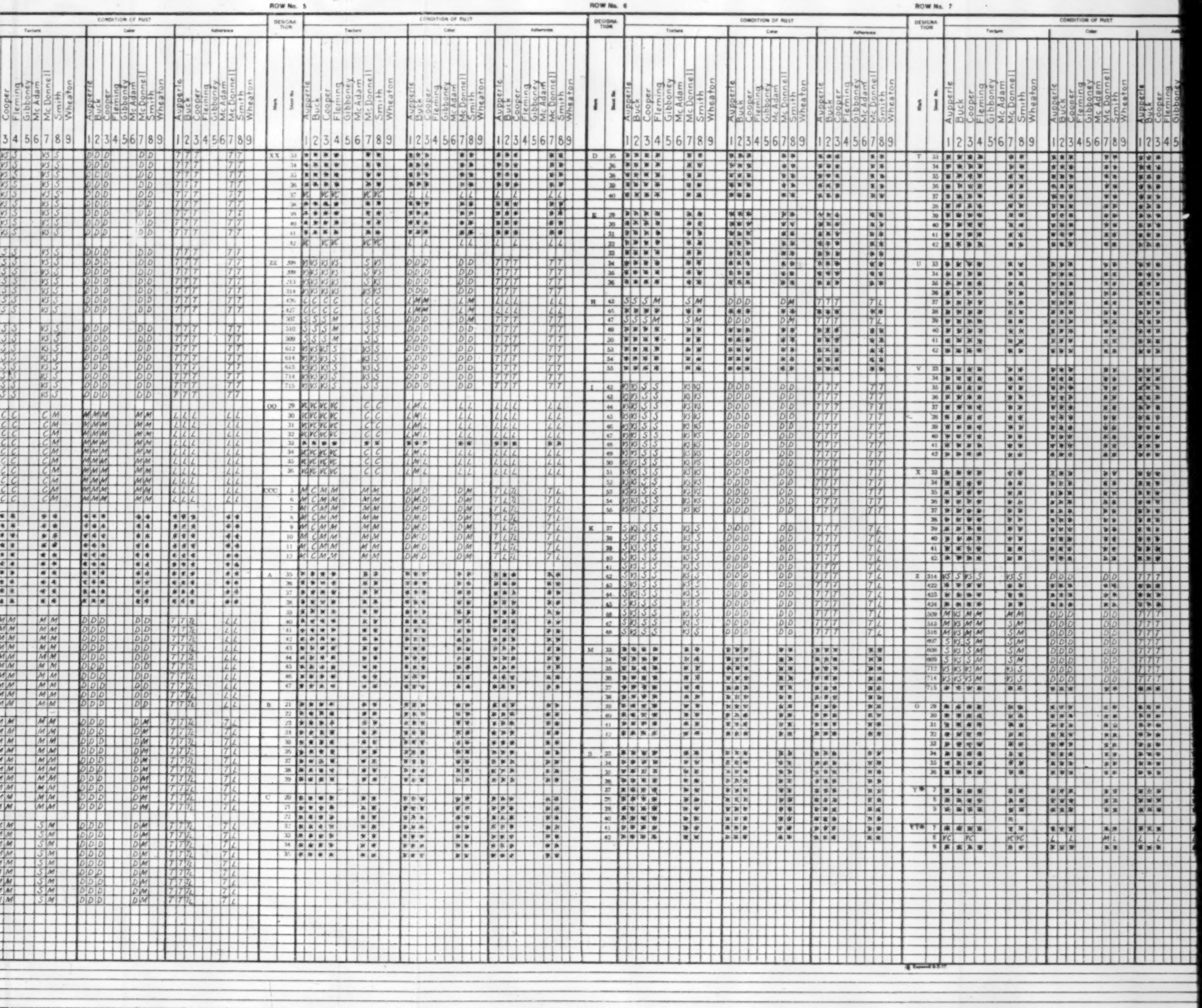
NOTES, (GENERAL)

Sheets Marked with Star (*) under "Condition of Rust", were not Considered for Detail Physical Inspection Due to Reported Failure.

TABLE V.—RESULTS OF INSPECTION OF CORROSION TEST SHEETS, AT PITTSBURGH, PA., APRIL 5, 1921.

AMERICAN SOCIETY FOR TESTING MATERIALS
COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
PITTSBURGH, PA.

EXPOSED DECEMBER 12 1916



ROW No. 5
ROW No. 6
ROW No. 7
DESIGNATION
Mark
Sheet No.
CONDITION OF RUST
Texture
Color
Adherence
Aupperle
Buck
Cooper
Fleming
Gibboney
McAdam
McDonnell
Smith
Wheaton
1 2 3 4 5 6 7 8 9

— The Following Sheets were Reported as Failures prior to this Inspection: —

AA – 21 to 30 incl.
AA – 50 to 56 incl.
OO – 27.
SS – 29 to 42 incl.
A – 31 to 47 incl.
B – 17, 18, 21 and 23.
B – 35 to 38 incl.

C – 11, 13 and 14.
C – 20 to 22 incl.
C – 32 to 35 incl.
D – 30, 31, 33, 34, 35 and 36.
D – 38 to 40 incl.
E – 25 to 36 incl.
M – 32, 36, 39, 41 and 42.

O – 25 to 36 incl.
S – 23 to 42 incl.
T – 29 to 42 incl.
U – 29, 30 and 31.
U – 33, 34, 35, 38, 40, 41 and 42.
V – 29 and 30.
V – 33 to 42 incl.

X – 29 to 42 incl.
Y – 7 to 9 incl.
Z – 6, 7, 11.
Z – 422, 423, 424.
ZZ – 8, 10, 14.
XX – 29 to 32 incl.
XX 36 and 41.

DD – 25 and 26.
OO – 25, 26, 28 and 33.
XX – 33, 34, 35, 38, 39 and 40.
YY – 7 and 9.
B – 22, 34 and 39.
C – 12.

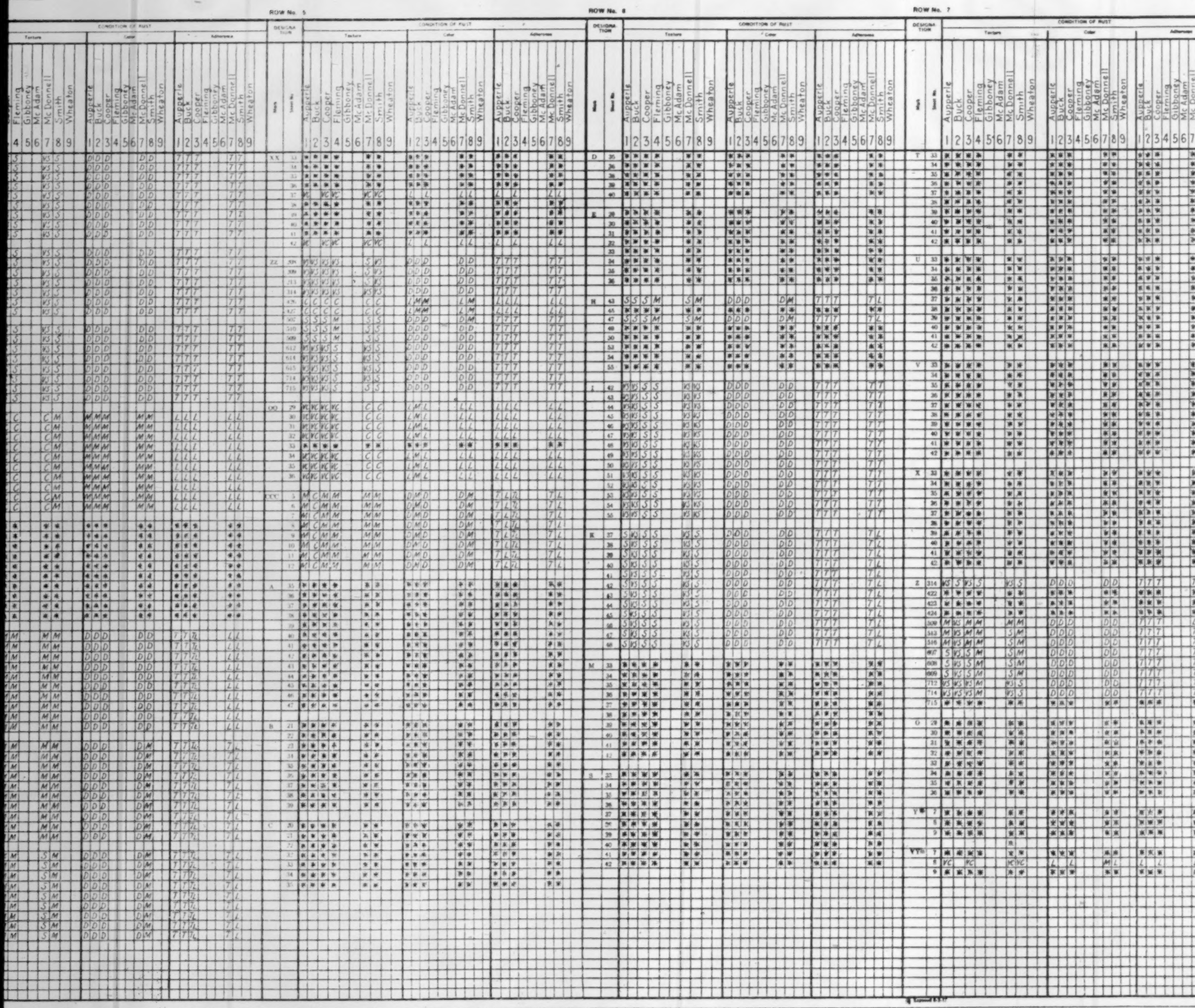
— The Following Sheets are Reported as Failures at this Inspection: —

H – 38, 40, 42, 45, 49, 50, 53, 54
M – 29, 30, 33, 34, 35, 37, 38 an
U – 32, 36, 37 and 39.
V – 31 and 32.
Z – 113 and 715.

Table V.—Results of Inspection of Corrosion Test Sheets, at Pittsburgh, Pa., April 5, 1921.

AMERICAN SOCIETY FOR TESTING MATERIALS
COMMITTEE A-5 ON CORROSION OF IRON AND STEEL
TESTS OF UNCOATED SHEETS
PITTSBURGH, PA.

EXPOSED DECEMBER 12 1916



ROW No. 5

ROW No. 6

ROW No. 7

CONDITION OF RUST

Texture

Color

Adherence

DESIGNATION

Mark

Sheet No.

Aupperle
Buck
Cooper
Fleming
Gibboney
McAdam
McDonnell
Smith
Wheaton

1 2 3 4 5 6 7 8 9

— The Following Sheets were Reported as Failures prior to this Inspection: —

AA – 21 to 30 incl.
AA – 50 to 55 incl.
OO – 27.
SS – 29 to 42 incl.
A – 31 to 47 incl.
B – 17, 18, 21 and 23.
B – 35 to 38 incl.

C – 11, 13 and 14.
C – 20 to 22 incl.
C – 32 to 35 incl.
D – 30, 31, 33, 34, 35 and 36.
D – 38 to 40 incl.
E – 25 to 36 incl.
M – 32, 36, 39, 41 and 42.

O – 25 to 36 incl.
S – 23 to 42 incl.
T – 29 to 42 incl.
U – 29, 30 and 31.
U – 33, 34, 35, 38, 40, 41 and 42.
V – 29 and 30.
V – 33 to 42 incl.

X – 29 to 42 incl.
Y – 7 to 9 incl.
Z – 6, 7, 11.
Z – 422, 423, 424.
ZZ – 8, 10, 14.
XX – 29 to 32 incl.
XX 36 and 41.

— The Following Sheets are Reported as Failures at this Inspection: —

DD – 25 and 26.
OO – 25, 26, 28 and 33.
XX – 33, 34, 35, 38, 39 and 40.
YY – 7 and 9.
B – 22, 34 and 39.
C – 12.

H – 38, 40, 42, 45, 49, 50, 53,
M – 29, 30, 33, 34, 35, 37, 38
U – 32, 36, 37 and 39.
V – 31 and 32.
Z – 113 and 715.

PLATE V.
PROC. AM. SOC. TEST. MATS.
VOL. 21.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

Weather *Fair and Warm.*

Adherence						
Cooper 3	Fleming 4	Gibboney 5	Mc Adam 6	Mc Donnell 7	Smith 8	Wheaton 9
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
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✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
7				7	7	
✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
7				L	7	
7				7	L	
7				7	L	
7				7	L	
7				7	L	
7				7	L	
7				7	7	
7				7	7	
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✱				✱	✱	
✱				✱	✱	
✱				✱	✱	
L				L	L	
✱				✱	✱	

Sheets DD – 25 and 26, Failed; Bottom Edge Ragged.
" OO – 25, 26 and 28, " ; Lower " " .
" C – 12, " ; Hole near Bottom.
" H – 38, 40 and 42, " ; " " " .
" M – 29 and 30, " ; " " " .
" U – 32, " ; " " " .
" V – 31 and 32, " ; " " " .
" Z – 113, " ; " " " .

Sheets XX – 33, 34, 35, 38, 39, 40, Failed, Hole near Bottom.
" YY – 7 and 9, " ; " " " .
" OO – 33, " ; " " " .
" B – 22, 34 and 39, " ; " " " .
H – 45, 49, 50, 53, 54 and 55, Failed.
I – 50, – Old Mechanical Injury.
M – 33, 34, 35, 37, 38 and 40, Failed.
U – 36, 37 and 39, Failed.

Sheet Z – 715, Failed.

0, 53, 54 and 55.
7, 38 and 40.

— W. R. FLEMING —

Color, – Could not Distinguish.
Adherence, – Useless to Attempt to Record it.

J. H. Gibboney
D. J. Mc Adam, Jr. } *Did not make this Inspection.*
F. B. Wheaton

James H Gibboney

[illegible]

TABLE VI.—FORT SHERIDAN TESTS. INSPECTION OF OCTOBER 11, 1920.

Type Designation.	Average Texture.		Color.	Adherence.
	Numerical Value.	Symbol.		
No. 16 Gage.				
ZZ (HC)	4.422	VS	D	T
KK	4.254	VS	D	T
II	4.008	S	D	T
BB	3.608	S	D	T
EE	3.583	S	D	T
HH	3.529	S	D	T
TT	3.405	S	D	T
UU	3.167	M	M	T
VV	3.000	M	M	T
MM	2.964	M	D	T
ZZ (LC)	2.666	M	M	T
CCC	2.375	C	M	L
YY	2.333	C	M	L
OO	2.083	C	M	L
DD	1.947	C	L	L
CC	1.931	C	L	L
XX	1.833	C	M	L
SS	1.750	VC	L	L
AA	1.333	VC	L	L
No. 22 Gage.				
I	4.614	VS	D	T
Z (HC)	4.277	VS	D	T
K	4.146	S	D	T
H	3.576	S	D	T
E	3.500	S	D	T
T	3.429	S	D	T
M	3.393	M	D	T
V	3.190	M	M	T
B	3.141	M	D	T
U	3.059	M	M	T
C	2.792	M	M	T
Y	2.353	C	M	L
Z (LC)	2.316	C	M	L
X	2.059	C	L	L
D	2.000	C	L	L
A	1.692	VC	M	L
S	1.429	VC	L	L

NOTE.—ZZ (HC) indicates copper 0.154 to 0.658 per cent.
ZZ (LC) indicates copper 0.031 per cent or under.
Z (HC) indicates copper 0.126 to 0.554 per cent.
Z (LC) indicates copper 0.020 per cent or under.

Nearly all of the O sheets exposed at Fort Sheridan are recorded as failure in this report, therefore no rating appears n this table.

The above table has been compiled from the composite inspection report by averaging the reports on texture on each sheet by each inspector. The arbitrary figures used in these averages are as follows:

Very coarse	1
Coarse	2
Medium	3
Smooth	4
Very Smooth	5

The numerical values thus obtained have been translated back into symbols, using the following scale:

1.0 to 1.8	Very coarse (VC)
1.8 to 2.6	Coarse (C)
2.6 to 3.4	Medium (M)
3.4 to 4.2	Smooth (S)
4.2 to 5.0	Very smooth (VS)

In the case of color and adherence, it being impractical to ascribe satisfactory numerical value, the symbols in the table represent the majority opinions of the inspectors.

committee, tables have been prepared from the composite reports for the inspections made during the past year.

Tables VI, VII, VIII, IX and X give in condensed form the results obtained by the averaging method for the condition of surfaces of sheets at Fort Sheridan, Pittsburgh and Annapolis in October, 1920, and at Fort Sheridan and Pittsburgh in April, 1921.

TABLE VII.—PITTSBURGH TESTS. INSPECTION OF OCTOBER 12, 1920.

Type Designation.	Average Texture.		Color.	Adherence.
	Numerical Value.	Symbol.		
No. 16 GAGE.				
II	4.828	VS	D	T
ZZ (HC)	4.500	VS	D	T
KK	4.458	VS	D	T
HH	4.009	S	D	T
TT	3.939	S	D	T
EE	3.881	S	D	T
UU	3.775	S	D	T
VV	3.527	S	D	T
CCC	2.988	M	M	T
BB	2.908	M	D	T
MM	2.663	M	M	L
CC	2.047	C	M	L
OO	1.619	VC	M	L
DD	1.127	VC	M	L
XX	1.000	VC	M	L
YY	1.000	VC	M	L
No. 22 GAGE.				
I	4.651	VS	D	T
Z (HC)	4.471	VS	D	T
K	4.428	VS	D	T
H	3.905	S	D	T
M	3.024	M	D	T

NOTE.—ZZ (HC) indicates copper 0.153 to 0.586 per cent.
Z (HC) indicates copper 0.128 to 0.712 per cent.

In the case of all of the A, D, O, S, X, E, Y, and AA sheets, recorded as complete failures in the 1919 and 1920 reports, no further detail records appear. All of the T, Z (LC), and SS, and a majority number of the B, U, C, V, and ZZ (LC) sheets, exposed at Pittsburgh, Pa., are recorded as failures in this report, therefore no rating appears in this table.

The above table has been compiled from the composite report by averaging the reports on texture on each sheet by each inspector. The arbitrary figures used in these averages are as follows:

Very coarse	1
Coarse	2
Medium	3
Smooth	4
Very smooth	5

The numerical values thus obtained have been translated back into symbols, using the following scale:

1.0 to 1.8	Very coarse (VC)
1.8 to 2.6	Coarse (C)
2.6 to 3.4	Medium (M)
3.4 to 4.2	Smooth (S)
4.2 to 5.0	Very smooth (VS)

In the case of color and adherence, it being impractical to ascribe satisfactory numerical values, the symbols in the table represent the majority opinions of the inspectors.

Tables XI and XII present in condensed form the results obtained by the averaging method for the condition of surface texture of the

TABLE VIII.—ANNAPOLIS TESTS. INSPECTION OF OCTOBER 13, 1920.

Type Designation.	Average Texture.		Color.	Adherence.
	Numerical Value.	Symbol.		
No. 16 GAGE.				
II	4.273	VS	D	T
KK	3.833	S	D	T
HH	3.703	S	D	T
ZZ (HC)	3.669	S	D	T
EE	3.594	S	M	T
TT	3.375	M	D	T
MM	3.223	M	M	T
BB	3.059	M	D	T
ZZ (LC)	2.750	M	M	T
UU	2.678	M	M	T
OO	2.594	C	M	L
VV	2.580	C	M	L
CC	2.531	C	L	L
DD	2.408	C	L	L
CCC	2.146	C	L	L
SS	1.875	C	L	L
AA	1.854	C	M	L
XX	1.804	C	L	L
YY	1.625	VC	L	L
No. 22 GAGE.				
K	3.898	S	D	T
I	3.844	S	D	T
Z (HC)	3.708	S	D	T
E	3.477	S	M	T
H	3.242	M	D	T
T	3.205	M	D	T
B	2.969	M	M	T
M	2.955	M	M	T
U	2.786	M	M	L
V	2.634	M	M	L
A	2.625	M	M	L
C	2.500	C	L	L
Z (LC)	2.437	C	M	L
Y	2.375	C	L	L
O	2.312	C	M	L
D	2.125	C	L	L
X	1.982	C	L	L
S	1.705	VC	L	L

NOTE.—ZZ (HC) indicates copper 0.162 to 0.662 per cent.
ZZ (LC) indicates copper 0.034 per cent or under.
Z (HC) indicates copper 0.138 to 0.654 per cent.
Z (LC) indicates copper 0.020 per cent or under.

The above table has been compiled from the composite inspection report by averaging the reports on texture on each sheet by each inspector. The arbitrary figures used in these averages are as follows:

Very coarse	1
Coarse	2
Medium	3
Smooth	4
Very smooth	5

The numerical values thus obtained have been translated back into symbols, using the following scale:

1.0 to 1.8	Very coarse (VC)
1.8 to 2.6	Coarse (C)
2.6 to 3.4	Medium (M)
3.4 to 4.2	Smooth (S)
4.2 to 5.0	Very smooth (VS)

In the case of color and adherence, it being impractical to ascribe satisfactory numerical values, the symbols in the table represent rhe majority opinions of the inspectors.

TABLE IX.—FORT SHERIDAN TESTS. INSPECTION OF APRIL 4, 1921.

Type Designation.	Average Texture.		Color.	Adherence.
	Numerical Value.	Symbol.		
	NO. 16 GAGE.			
II	4.632	VS	D	T
KK	4.453	VS	D	T
ZZ (HC)	4.055	S	D	T
HH	3.800	S	D	T
EE	3.800	S	D	T
BB	3.635	S	D	T
TT	3.600	S	D	T
UU	3.200	M	M	T
MM	3.043	M	D	T
VV	3.032	M	M	T
OO	2.600	M	M	L
ZZ (L C)	2.500	C	M	L
DD	2.295	C	L	L
CCC	2.250	C	M	L
YY	2.200	C	M	L
CC	2.150	C	L	L
AA	1.856	C	L	L
XX	1.843	C	L	L
SS	1.600	VC	L	L
	NO. 22 GAGE.			
I	4.600	VS	D	T
K	4.163	S	D	T
Z (HC)	4.100	S	D	T
T	3.686	S	D	T
E	3.650	S	D	T
H	3.600	S	D	T
V	3.243	M	M	T
M	3.229	M	D	T
U	3.086	M	M	T
B	3.046	M	M	T
C	2.800	M	M	L
D	2.300	C	L	L
Y	2.300	C	M	L
X	1.846	C	L	L
A	1.600	VC	M	L
S	1.557	VC	L	L

NOTE.—ZZ (HC) indicates copper 0.154 to 0.658 per cent.
ZZ (LC) indicates copper 0.031 per cent or under.
Z (HC) indicates copper 0.126 to 0.554 per cent.
Z (LC) indicates copper 0.020 per cent or under.

Nearly all of the O and Z (LC) sheets, exposed at Fort Sheridan, are recorded as failures in this report, therefore no rating appears in this table.

The above table has been compiled from the composite report by averaging the reports on texture on each sheet by each inspector. The arbitrary figures used in these averages are as follows:

Very coarse	1
Coarse	2
Medium	3
Smooth	4
Very smooth	5

The numerical values thus obtained have been translated back into symbols, using the following scale:

1.0 to 1.8	Very coarse (VC)
1.8 to 2.6	Coarse (C)
2.6 to 3.4	Medium (M)
3.4 to 4.2	Smooth (S)
4.2 to 5.0	Very smooth (VS)

In the case of color and adherence, it being impractical to ascribe satisfactory numerical values, the symbols in table represent the majority opinions of the inspectors.

sheets at Pittsburgh and Fort Sheridan for all inspections. By comparing this information with failures at these locations, representing different atmospheric conditions, it will be observed that the groups of sheets of similar composition have shown substantially the same surface texture development at both locations, and that while the rate of failure has been different the condition of surface texture appears to be a reliable guide as regarding rate of corrosion, the coarseness of texture usually accompanied by a light yellow, loose adhering rust, being apparently directly proportional to increased rate of corrosion.

TABLE X.—PITTSBURGH TESTS. INSPECTION OF APRIL 5, 1921.

Type Designation.	Average Texture.		Color.	Adherence.
	Numerical Value.	Symbol.		
No. 16 Gage.				
II	4.787	VS	D	T
ZZ (HC)	4.466	VS	D	T
KK	4.404	VS	D	T
HH	3.967	S	D	T
VV	3.487	S	D	T
TT	3.452	S	D	T
UU	3.357	M	D	T
EE	3.944	S	D	T
CCC	3.111	M	D	T
BB	2.647	M	M	L
MM	2.309	C	M	L
CC	1.819	C	M	L
OO	1.333	VC	L	L
DD	1.021	VC	L	L
No. 22 Gage.				
I	4.556	VS	D	T
K	4.292	VS	D	T
Z (HC)	4.033	S	D	T

NOTE.—ZZ (HC) indicates copper 0.153 to 0.586 per cent.
Z (HC) indicates copper 0.128 to 0.712 per cent.

In the case of all of the A, D, O, S, X, E, Y, and AA sheets, exposed at Pittsburgh, Pa., recorded as complete failures in the 1919 and 1920 reports, no further detail records appear. All of the C, T, U, V, Z (LC), SS, and a majority number of the B, M, H, XX, YY, and ZZ (LC) sheets exposed at Pittsburgh, Pa., are recorded as failures in this report, therefore no rating appears in this table.

The above table has been compiled from the composite inspection report by averaging the reports on texture on each sheet by each inspector. The arbitrary figures used in these averages are as follows:

Very coarse	1
Coarse	2
Medium	3
Smooth	4
Very smooth	5

The numerical values thus obtained have been translated back into symbols, using the following scale:

1.0 to 1.8	Very coarse (VC)
1.8 to 2.6	Coarse (C)
2.6 to 3.4	Medium (M)
3.4 to 4.2	Smooth (S)
4.2 to 5.0	Very smooth (VS)

In the case of color and adherence, it being impractical to ascribe satisfactory numerical values, the symbols in the table represent the majority opinions of the inspectors.

TABLE XI.—AVERAGE SURFACE TEXTURE, PITTSBURGH TESTS. INSPECTION OF 1917, 1918, 1919, 1920 AND APRIL, 1921.
SHEETS EXPOSED, DECEMBER 12, 1916.

Group.	Type Designation.	Date of Inspection.															
		Oct. 9, 1917.		April 9, 1918.		Oct. 7, 1918.		April 1, 1919.		Nov. 5, 1919.		May 11, 1920.		Oct. 12, 1920.		April 5, 1921.	
		Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.
		No. 16 Gage.															
HH	Copper-bearing Basic Open-Hearth Steel, Series A	3.725	S	3.603	S	4.025	S	3.883	S	4.044	S	3.896	S	4.009	S	3.967	S
ZZ(HC)	Copper-bearing Steel, Series B, Youngstown Sheet and Tube Co.	3.684	S	4.266	VS	4.500	VS	4.267	VS	4.389	VS	4.333	VS	4.500	VS	4.466	VS
II	Copper-bearing Bessemer Steel, Series A	3.597	S	4.389	VS	4.431	VS	4.271	VS	4.666	VS	4.358	VS	4.825	VS	4.787	VS
TT	Copper-bearing Steel, Series B, Newport Rolling Mill Co.	3.572	S	3.589	S	3.982	S	4.071	S	3.690	S	3.666	S	3.939	S	3.452	S
KK	Copper-bearing Acid Open-Hearth Steel, Series A	3.428	S	4.171	S	4.177	S	4.178	S	4.140	S	4.053	S	4.458	VS	4.404	VS
UU	Copper-bearing Pure Iron, Series B, Allegheny Steel Co.	3.339	M	3.518	S	3.839	S	3.907	S	3.524	S	3.492	S	3.775	S	3.357	M
CCC	Copper-bearing Pure Iron, Series A	3.219	M	3.333	M	3.333	M	3.130	M	3.333	M	3.074	M	2.988	M	3.111	M
EE	Puddled Iron, Series A	3.208	M	3.542	S	3.813	S	3.792	S	4.028	S	3.722	S	3.881	S	3.944	S
BB	Open-hearth Steel, Series A	3.100	M	3.037	M	2.860	M	2.941	M	3.010	M	2.752	M	2.904	M	2.647	M
VV	Copper-bearing Pure Iron, Series B, Whitaker-Glessner Co.	3.087	M	3.529	S	3.923	S	3.910	S	3.538	S	3.393	M	3.527	S	3.487	S
YY*a*	Low-Copper Wrought Iron, Series B, Youngstown Sheet and Tube Co.	......	....	3.000	M	2.000	C	1.625	VC	1.333	VC	1.111	VC	1.000	VC	......	....
CC	Copper-bearing Pure Iron, Series A	2.970	M	2.812	M	2.625	M	2.344	C	2.167	C	2.065	C	2.047	C	1.819	C
MM	Open-hearth Steel, Series B, Alan Wood Iron and Steel Co.	2.857	M	2.357	C	2.804	M	2.536	C	2.405	C	2.222	C	2.663	M	2.309	C
DD	Low-Copper Pure Iron, Series A	2.521	C	2.215	C	2.139	C	1.409	VC	1.528	VC	1.296	VC	1.127	VC	1.021	VC
OO	Low-Copper Open-hearth Steel, Series A	2.167	C	1.500	VC	2.083	C	1.708	VC	1.833	C	1.407	VC	1.619	VC	1.533	VC
ZZ(LC)	Low-Copper Steel, Series B, Youngstown Sheet and Tube Co.	2.150	C	1.600	VC	2.375	VC	1.450	VC	2.067	C	......	....	......	....	......	....
XX	Low-Copper Pure Iron, Series B, Inland Steel Co.	1.996	C	1.750	VC	1.643	VC	1.482	VC	1.119	VC	......	....	......	....	......	....
SS	Low-Copper Pure Iron, Series B, American Rolling Mill Co.	1.822	C	1.625	VC	1.125	VC	1.000	VC	1.000	VC	......	....	......	....	......	....
AA	Bessemer Steel, Series A	1.162	VC	1.000	VC	1.037	VC	1.000	VC	1.143	VC	......	....	......	....	......	....

NOTE.—ZZ(HC) indicates copper 0.153 to 0.586 per cent.
ZZ(LC) indicates copper 0.034 per cent or under.

a YY Sheets exposed June 2, 1917.

TABLE XI—(*Continued*).

Group.	Type Designation.	Date of Inspection															
		Oct. 9, 1917.		April 9, 1918.		Oct. 7, 1918.		April 1, 1919.		Nov. 5, 1919.		May 11, 1920.		Oct. 12, 1920.		April 5, 1921.	
		Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.
		No. 22 Gage.															
Z(HC)	Copper-bearing Steel, Series B, Youngstown Sheet and Tube Co.	3.828	S	4.008	S	4.294	VS	4.522	VS	4.294	VS	4.131	S	4.471	VS	4.033	S
I	Copper-bearing Bessemer Steel, Series A	3.819	S	4.118	S	4.472	VS	4.084	S	4.092	S	4.136	S	4.651	VS	4.556	VS
H	Copper-bearing Basic Open-hearth Steel, Series A	3.792	S	3.572	S	4.000	S	3.958	S	3.444	S	3.777	S	3.905	S	......	....
K	Copper-bearing Acid Open-hearth Steel, Series A	3.719	S	4.062	S	4.187	S	4.188	S	3.833	S	4.083	S	4.428	VS	4.292	VS
B	Open-Hearth Steel, Series A	3.653	S	3.211	M	3.567	S	3.202	M	2.803	M	......	....	......	....	......	....
T	Copper-bearing Steel, Series B, Newport Rolling Mill Co.	3.589	S	3.482	S	4.107	S	3.821	S	3.619	S	......	....	......	....	......	....
U	Copper-bearing Pure Iron, Series B, Allegheny Steel Co.	3.554	S	3.232	M	3.875	S	3.696	S	3.548	S	......	....	......	....	......	....
V	Copper-bearing Pure Iron, Series B, Whitaker-Glessner Co.	3.464	S	3.304	S	3.839	S	3.536	S	3.286	M	......	....	......	....	......	....
Y[a]	Low-Copper Wrought Iron, Series B, Youngstown Sheet and Tube Co.	......	....	3.250	M	2.500	C	1.625	VC	1.667	VC	......	....	......	....	......	....
C	Copper-bearing Pure Iron, Series A	3.364	M	2.864	M	3.273	M	3.204	M	2.606	M	......	....	......	....	......	....
M	Open-hearth Steel, Series B, Alan Wood Iron and Steel Co.	3.330	M	3.107	M	2.732	M	3.108	M	3.238	M	......	....	......	....	......	....
E	Puddled Iron, Series A	3.125	M	3.250	M	3.385	M	3.270	M	3.062	M	......	....	......	....	......	....
D	Low-Copper Pure Iron, Series A	2.431	C	1.833	C	1.667	VC	1.333	VC	......	....	......	....	......	....	......	....
Z(LC)	Low-Copper Steel, Series B, Youngstown Sheet and Tube Co.	2.142	C	1.803	C	1.813	C	1.187	VC	1.000	VC	......	....	......	....	......	....
S	Low-Copper Pure Iron, Series B, American Rolling Mill Co.	1.893	C	1.625	VC	1.000	VC	1.000	VC	......	....	......	....	......	....	......	....
X	Low-Copper Pure Iron, Series B, Inland Steel Co	1.491	VC	1.268	VC	1.214	VC	1.125	VC	......	....	......	....	......	....	......	....
A	Bessemer Steel, Series A	1.346	VC	1.000	VC	1.125	VC	1.029	VC	......	....	......	....	......	....	......	....
O	Low-Copper, Open-hearth Steel, Series A	1.209	VC	1.000	VC	1.091	VC	1.167	VC	......	....	......	....	......	....	......	....

NOTE.—Z(HC) indicates copper 0.126 to 0.712 per cent.
Z(LC) indicates copper 0.019 per cent or under.

[a] YY and Y sheets exposed June 2, 1917.

In the case of all of the A, D, O, S, X, E, Y and AA sheets, exposed **at** Pittsburgh, **Pa., recorded as** complete failures in the 1919 and 1920 reports, no further detail records appear. All **of** the **C, T**, U, V, Z **(Low Copper)**, SS, and a majority number of the **B, M, H, XX, YY and ZZ (Low Copper)** sheets exposed at Pittsburgh, Pa., are recorded **as failures** in this report; there**fore, no rating appears in this table.**

The above table has been compiled from the composite inspection reports **by averaging the reports on texture** on each sheet by each inspector. The **arbitrary figures** used in these **averages** and the scale used for translating back into symbols are the same as given for Tables VI to X inclusive.

TABLE XII.—AVERAGE SURFACE TEXTURE, FORT SHERIDAN TESTS. INSPECTIONS OF 1917, 1918, 1919, 1920, AND APRIL, 1921. SHEETS EXPOSED APRIL 9, 1917.

Group.	Type Designation	Date of Inspection.											
		Oct. 8, 1917.		April 8, 1918.		Mar. 31, 1919.		May 10, 1920.		Oct. 11, 1920.		April 4, 1921.	
		Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.
		No. 16 Gage.											
BB	Open-hearth Steel, Series A	3.765	S	3.721	S	3.252	M	3.470	M	3.608	S	3.635	S
II	Copper-bearing Bessemer Steel, Series A	3.763	S	4.689	S	3.977	S	3.934	S	4.008	S	4.632	VS
KK	Copper-Bearing Acid Open-hearth Steel, Series A	3.750	S	4.006	S	4.098	S	4.085	S	4.254	VS	4.453	VS
HH	Copper-bearing Basic Open-hearth Steel, Series A	3.500	S	3.875	S	3.756	S	3.625	S	3.529	S	3.800	S
DD	Low-Copper Pure Iron, Series A	3.369	M	3.053	M	2.782	M	2.474	C	1.947	C	2.295	C
UU	Copper-bearing Pure Iron, Series B, Allegheny Steel Co.	3.346	M	3.307	M	3.286	M	3.279	M	3.167	M	3.200	M
ZZ(HC)	Copper-bearing Steel, Series B, Youngstown Sheet and Tube Co.	3.341	M	4.011	S	4.156	S	4.023	S	4.422	VS	4.055	S
VV	Copper-bearing Pure Iron, Series B, Whitaker-Glessner Co.	3.217	M	3.316	M	3.286	M	3.099	M	3.000	M	3.032	M
TT	Copper-Bearing Steel, Series B, Newport Rolling Mill Co.	3.187	M	3.205	M	3.571	S	3.580	S	3.405	S	3.600	S
EE	Puddled Iron, Series A	3.156	M	3.594	S	3.357	M	3.281	M	3.583	S	3.800	S
CC	Copper-bearing Pure Iron, Series A	3.031	M	2.906	M	2.583	C	2.635	M	1.931	C	2.150	C
XX	Low-Copper Pure Iron, Series B, Inland Steel Co.	2.750	M	2.348	C	2.122	C	2.330	C	1.833	C	1.843	C
SS	Low-Copper Pure Iron, Series B, American Rolling Mill Co.	2.625	M	2.281	C	2.143	C	2.250	C	1.750	VC	1.600	VC
OO	Low-Copper Open-hearth Steel, Series A	2.511	C	2.234	C	2.643	M	2.281	C	2.083	C	2.600	M
CCC	Copper-bearing Pure Iron, Series A	2.479	C	2.469	C	2.750	M	2.750	M	2.375	C	2.250	C
MM	Open-Hearth Steel, Series B, Alan Wood Iron and Steel Co.	2.348	C	2.330	C	2.663	M	2.929	M	2.964	M	3.043	M
ZZ(LC)	Low-Copper Steel, Series B, Youngstown Sheet and Tube Co.	2.250	C	2.625	M	2.571	C	2.500	C	2.666	M	2.500	C
AA	Bessemer Steel, Series A	1.577	VC	1.771	VC	1.802	C	1.368	VC	1.333	VC	1.856	C
YY[a]	Low-Copper Wrought Iron, Series B, Youngstown Sheet and Tube Co.	....	......	2.625	M	2.143	C	2.125	C	2.333	C	2.200	C

NOTE.—ZZ(HC) indicates copper 0.154 to 0.658 per cent.
ZZ(LC) indicates copper 0.031 per cent or under.

[a] YY sheets exposed June 13, 1917.

TABLE XII—(*Continued*).

Group.	Type Designation.	Date of Inspection.											
		Oct. 8, 1917.		April 8, 1918.		Mar. 31, 1919.		May 10, 1920.		Oct. 11, 1920.		April 14, 1921.	
		Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.	Numerical Value.	Symbol.
		No. 22 Gage.											
Z(HC)	Copper-Bearing Steel, Series B, Youngstown Sheet and Tube Co.	3.985	S	4.271	VS	4.120	S	4.114	S	4.277	VS	4.100	S
I	Copper-Bearing Bessemer Steel, Series A	3.694	S	4.105	S	4.000	S	4.125	S	4.614	VS	4.600	VS
B	Open-hearth Steel, Series A	3.529	S	3.317	M	3.209	M	3.096	M	3.141	M	3.046	M
H	Copper-Bearing Basic Open-hearth Steel, Series A	3.500	S	3.625	S	3.402	S	3.716	S	3.576	S	3.600	S
T	Copper-Bearing Steel, Series B, Newport Rolling Mill Co.	3.447	S	3.625	S	3.479	S	3.545	S	3.429	S	3.686	S
K	Copper-Bearing Acid Open-hearth Steel, Series A	3.414	S	3.570	S	4.116	S	4.047	S	4.146	S	4.163	S
V	Copper-bearing Pure Iron, Series B, Whitaker-Glessner Co.	3.331	M	3.321	M	3.592	S	3.295	M	3.190	M	3.243	M
M	Open-hearth Steel, Series B, Alan Wood Iron and Steel Co.	3.295	M	3.232	M	3.061	M	3.468	M	3.393	M	3.229	M
C	Copper-bearing Pure Iron, Series A	3.261	M	3.146	M	3.218	M	2.844	M	2.792	M	2.800	M
D	Low-Copper Pure Iron, Series A	3.125	M	2.875	M	2.572	C	2.313	C	2.000	C	2.300	C
E	Puddled Iron, Series A	3.081	M	3.333	M	3.285	M	3.219	M	3.500	S	3.650	S
U	Copper-bearing Pure Iron, Series B, Allegheny Steel Co.	2.884	M	2.875	M	3.122	M	3.071	M	3.059	M	3.086	M
S	Low-Copper Pure Iron, Series B, American Rolling Mill Co.	2.759	M	2.000	C	2.061	C	1.946	C	1.429	VC	1.557	VC
X	Low-Copper Pure Iron, Series B, Inland Steel Co.	2.536	C	2.250	C	2.316	C	2.098	C	2.059	C	1.846	C
Z(LC)	Low-Copper Steel, Series B, Youngstown Sheet and Tube Co.	2.219	C	2.375	C	2.385	C	2.000	C	2.316	C	....	......
O	Low-Copper Open-hearth Steel, Series A	1.895	C	1.625	VC	1.857	C	1.386	VC	....	......	....	......
A	Bessemer Steel, Series A	1.584	VC	1.550	VC	1.828	C	1.564	VC	1.692	VC	1.600	VC
Y*a*	Low-Copper Wrought Iron, Series B, Youngstown Sheet and Tube Co.	....	......	2.708	M	2.095	C	2.375	C	2.353	C	2.300	C

NOTE.—Z(HC) indicates copper 0.126 to 0.554 per cent.
Z(LC) indicates copper 0.020 per cent or under.

[a] Y Sheets exposed June 13, 1917.

Nearly all of the O and Z (LC) sheets exposed at Fort Sheridan are recorded as failures in this report, therefore, no rating appears in this table.

The above table has been compiled from the composite inspection reports by averaging the reports on texture on each sheet by each inspector. The arbitrary figures used in these averages and the scale for translating back into symbols are the same as given for Tables VI to X, inclusive.

In the 1920 report of the sub-committee, Table X, the sheets at the Pittsburgh location were shown grouped as regarding the presence of copper, into copper-bearing and non-copper-bearing metals, indicating the failures present in each group of sheets at all inspection periods, which data led to the observation that the failures at this location were confined mainly to the non-copper-bearing metals. Table XIII is presented as the continuation of the same plan of grouping the sheets at Pittsburgh, recording such additional failures as have occurred during the past year. A summary of this data, grouping the heavy and light gage sheets according to copper content into copper-bearing and non-copper-bearing metals and showing the percentage rate of failure in each group of sheets at each inspection in terms of total sheets, is presented in an effort to offer a ready means for comparing rust resisting properties of copper-bearing and non-copper-bearing metals under atmospheric exposure of uncoated sheets at this location.

Type Designation.	Gage.	Number of Groups.	Total Number of Sheets.	Number Failed.	Total Failures at Each Inspection, Expressed as Percentages of Total Sheets of Each Type Exposed.							
					10 Mo.	16 Mo.	22 Mo.	28 Mo.	35 Mo.	41 Mo.	46 Mo.	52 Mo.
Copper-Bearing	16	14	132	none	....	....	....	....	....	....	....	....
Non-Copper-Bearing	16	11	126	54	none	none	none	10.3	15.9	26.2	32.6	42.9
Copper-Bearing	22	15	146	93	none	none	1.4	4.1	13.7	27.4	44.5	63.7
Non-Copper-Bearing	22	11	84	82	none	35.7	79.7	91.6	94.0	96.4	96.4	97.6

It will be observed that the heavier gage non-copper-bearing sheets showed failures at the end of 28 months, with additional failures at each subsequent inspection, so that at the present time 42.9 per cent of these sheets have failed, whereas the heavier gage copper-bearing sheets have not shown any failures up to the time of the last inspection.

The failures in the lighter gage non-copper-bearing sheets appeared very prominently in the early periods of the test, 91.6 per cent of these sheets having failed at the end of 28 months, whereas for this same period only a few copper-bearing sheets had failed, and while at the end of 52 months' exposure 63.6 per cent of the lighter gage copper-bearing sheets had failed this result on the whole represents a superior condition to that found for the non-copper-bearing sheets at the end of the 28-month exposure period.

The results of the observations at the Pittsburgh tests have now reached a point where we may definitely conclude that copper-bearing metal shows marked superiority in rust-resisting properties as com-

TABLE XIII.—FAILURES AT PITTSBURGH TESTS. INSPECTIONS OF 1917, 1918, 1919, 1920 AND APRIL, 1921. SHEET

Group.	Designation.	Series.	Description.	Average Analysis.					
				Carbon.	Manganese.	Phosphorus.	Sulfur.	Silicon.	Copper.
No. 16 GAGE SH									
EE	Puddled Iron	A	Copper-bearing	0.035	0.03	0.119	0.018	0.125	0.319
HH	Copper-bearing Basic Open-Hearth Steel	A	" "	0.074	0.373	0.011	0.026	0.004	0.237
II	Copper-bearing Bessemer Steel	A	" "	0.059	0.371	0.095	0.066	0.006	0.247
KK	Copper-bearing Acid Open-Hearth Steel	A	" "	0.108	0.433	0.085	0.043	0.005	0.234
CCC	Copper-bearing Pure Iron	A	" "	0.023	0.026	0.005	0.028	0.005	0.236
TT	Copper-bearing Steel, Newport Rolling Mill Co.	B	" "	0.080	0.313	0.009	0.020	0.006	0.223
UU	Copper-bearing Pure Iron, Allegheny Steel Co.	B	" "	0.018	0.066	0.008	0.028	0.005	0.239
VV	Copper-bearing Pure Iron, Whitaker Glessner Co.	B	" "	0.018	0.046	0.007	0.019	0.004	0.299
ZZ	Copper-bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.08	0.40	0.092	0.037	0.004	0.153
Z	Copper-bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.09	0.31	0.088	0.047	.....	0.271
ZZ	Copper-bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.36	0.085	0.033	.....	0.549
ZZ	Copper-bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.37	0.054	0.064	.....	0.223
ZZ	Copper-bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.09	0.33	0.032	0.056	0.003	0.575
ZZ	Copper-bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.40	0.056	0.048	.....	0.364
	Total	.....	.....	.....	.....	.....	.....	.....	.....
AA	Bessemer Steel	A	Non-Copper-bearing	0.043	0.419	0.083	0.042	0.004	0.012
BB	Open-Hearth Steel	A	" " "	0.056	0.349	0.022	0.048	0.037	0.113
CC	Copper-bearing Pure Iron	A	" " "	0.019	0.029	0.004	0.032	0.003	0.067
DD	Low-copper Pure Iron	A	" " "	0.019	0.028	0.004	0.027	0.004	0.028
OO	Low-copper Open-Hearth Steel	A	" " "	0.108	0.371	0.009	0.029	0.007	0.029
MM	Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" " "	0.017	0.414	0.010	0.029	0.007	0.057
SS	Low-copper Pure Iron, American Rolling Mill Co.	B	" " "	0.017	0.021	0.006	0.021	0.006	0.025
XX	Low-copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.062	0.008	0.030	0.005	0.028
YY	Low-copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.051	0.123	0.019	0.203	0.023
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.07	0.40	0.097	0.037	0.008	0.013
ZZ	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.032	0.40	0.044	0.028	.....	0.028
	Total	.....	.....	.....	.....	.....	.....	.....	.....
No. 22 GAGE SHE									
B	Open-Hearth Steel	A	Copper-bearing	0.06	0.27	0.014	0.053	0.006	0.179
C	Copper-bearing Pure Iron	A	" "	0.015	0.028	0.006	0.036	0.003	0.190
E	Puddled Iron	A	" "	0.033	0.034	0.114	0.021	0.134	0.283
H	Copper-bearing Basic Open-Hearth Steel	A	" "	0.069	0.387	0.016	0.027	0.004	0.244
I	Copper-bearing Bessemer Steel	A	"	0.041	0.365	0.097	0.068	0.008	0.252
K	Copper-bearing Acid Open-Hearth Steel	A	" "	0.107	0.447	0.091	0.046	0.004	0.237
M	Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" "	0.093	0.419	0.013	0.041	0.011	0.185
T	Copper-bearing Steel, Newport Rolling Mill Co.	B	" "	0.083	0.313	0.009	0.020	0.005	0.227
U	Copper-bearing Pure Iron, Allegheny Steel Co.	B	" "	0.017	0.074	0.008	0.037	0.005	0.260
V	Copper-bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.051	0.007	0.021	0.005	0.304
Z	Copper-bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.039	0.37	0.084	0.038	0.007	0.257
Z	Copper-bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.043	0.37	0.100	0.045	.....	0.533
Z	Copper-bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.35	0.049	0.059	.....	0.212
Z	Copper-bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.39	0.059	0.058	.....	0.268
Z	Copper-bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.41	0.050	0.050	.....	0.621
	Total	.....	.....	.....	.....	.....	.....	.....	.....
A	Bessemer Steel	A	Non-Copper-bearing	0.038	0.386	0.089	0.040	0.007	0.014
B	Open-Hearth Steel	A	" " "	0.09	0.38	0.017	0.062	0.036	0.082
C	Copper-bearing Pure Iron	A	" " "	0.01	0.028	0.002	0.027	0.002	0.139
D	Low-copper Pure Iron	A	" " "	0.02	0.026	0.004	0.022	0.002	0.024
O	Low-copper Open-Hearth Steel	A	" "	0.121	0.536	0.008	0.030	0.249	0.020
S	Low-copper Pure Iron, American Rolling Mill Co.	B	" "	0.02	0.023	0.006	0.022	0.004	0.022
X	Low-copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.055	0.007	0.031	0.004	0.027
Y	Low-copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.055	0.139	0.021	0.218	0.020
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.055	0.37	0.119	0.048	0.003	0.013
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.07	0.40	0.088	0.048	0.009	0.133
Z	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.10	0.32	0.069	0.044	0.002	0.018
	Total	.....	.....	.....	.....	.....	.....	.....	.....

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[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above 0.15 per cent as copper-bearing.

[2] These "Y" Sheets were reported as failures at the Nov. 5 1919, inspection, but are placed in this column because they were exposed about six months later tha

PLATE VI.
PROC. AM. SOC. TEST. MATS.
VOL. 21.
REPORT OF COMMITTEE A-5:
CORROSION TESTS.

SHEETS EXPOSED DECEMBER 12, 1916. COMPARING COPPER-BEARING WITH NON-COPPER-BEARING MATERIALS.

	Number of Sheets in Test.	Date of Inspection.								Number of Sheets Failed in Test.
Copper.		Oct. 9, 1917. 10 Months.	April 9, 1918. 16 Months.	Oct. 7, 1918. 22 Months.	April 1, 1919. 28 Months.	Nov. 5, 1919. 35 Months.	May 11, 1920. 41 Months.	Oct. 12, 1920. 46 Months.	April 5, 1921. 52 Months.	
GAGE SHEETS.										
0.319	12	None	None	None	None	None	None	None	None	None
0.237	15	None	None	None	None	None	None	None	None	None
0.247	18	None	None	None	None	None	None	None	None	None
0.234	19	None	None	None	None	None	None	None	None	None
0.236	12	None	None	None	None	None	None	None	None	None
0.223	14	None	None	None	None	None	None	None	None	None
0.239	14	None	None	None	None	None	None	None	None	None
0.299	13	None	None	None	None	None	None	None	None	None
0.153	1	None	None	None	None	None	None	None	None	None
0.271	3	None	None	None	None	None	None	None	None	None
0.549	3	None	None	None	None	None	None	None	None	None
0.223	3	None	None	None	None	None	None	None	None	None
0.575	3	None	None	None	None	None	None	None	None	None
0.364	2	None	None	None	None	None	None	None	None	None
.....	132	None	None	None	None	None	None	None	None	None
0.012	17	None	None	None	25, 26, 27, 28, 29 30, 50, 51, 52, 53 54, 55, 56 (13)	21, 22, 23, 24, (4)	.....	.....	.....	17
0.113	17	None	None	None	None	None	None	None	None	None
0.067	12	None	None	None	None	None	None	None	None	None
0.028	18	None	None	None	None	None	None	None	25, 26 (2)	2
0.029	12	None	None	None	None	None	None	27 (1)	25, 26, 28 (3)	4
0.057	14	None	None	None	None	None	None	None	None	None
0.025	14	None	None	None	None	None	29, 30, 31, 32, 33 35, 39, 40 (8)	34, 36, 37, 38, 41 42 (6)	.....	14
0.028	14	None	None	None	None	None	29, 30, 31, 32 41 (5)	36 (1)	33, 34, 35, 38 39, 40 (6)	12
0.023	3	None	None	None	None	None	None	None	7, 9, (2)	2
0.013	3	None	None	None	None	8, 10, 14 (3)				3
0.028	2	None	None	None	None	None	None	None	None	None
.....	126	None	None	None	13	7	13	8	13	54
AGE SHEETS.										
0.179	9	None	None	None	None	17 (1)	18 (1)	21, 23 (2)	22, 34, 39 (3)	7
0.190	9	None	None	None	None	11, 13, 14, 22 (4)	32, 34, 35 (3)	33 (1)	12 (1)	9
0.283	12	None	None	32, 36 (2)	29, 30, 31 35 (4)	25, 27, 33, 34 (4)	26, 28 (2)	.....	.....	12
0.244	12	None	None	None	None	None	None	None	38, 40, 42, 45, 49 50, 53, 54, 55 (9)	9
0.252	18	None	None	None	None	None	None	None	None	None
0.237	16	None	None	None	None	None	None	None	None	None
0.185	14	None	None	None	None	None	32, 36, 42 (3)	39, 41 (2)	29, 30, 33, 34, 35 37, 38, 40 (8)	13
0.227	14	None	None	None	None	37, 39 (2)	32, 33, 35 36, 38 (5)	29, 30, 31, 34, 40 41, 42 (7)	.....	14
0.260	14	None	None	None	None	41 (1)	29, 30, 40 (3)	31, 33, 34, 35, 38 42 (6)	32, 36, 37 39 (4)	14
0.304	14	None	None	None	None	29, 39 (2)	36, 37, 42 (3)	30, 33, 34, 35, 38 40, 41 (7)	31, 32 (2)	14
0.257	3	None	None	None	None	None	None	None	None	None
0.533	2	None	None	None	None	None	None	None	None	None
0.212	3	None	None	None	None	None	None	None	None	None
0.268	3	None	None	None	None	None	None	None	None	None
0.621	3	None	None	None	None	None	None	None	715 (1)	1
.....	146	None	None	2	4	14	20	25	28	93
0.014	17	None	31, 32. 33, 34, 35 36, 37, 38. 40, 41 42, 43, 44, 45, 46 47 (16)	39 (1)	.....	.....	.....	.....	.....	17
0.082	4	None	None	37 (1)	38 (1)	35 (1)	36 (1)	.....	.....	4
0.139	2	None	None	None	None	20 (1)	21 (1)	.....	.....	2
0.024	9	None	None	30, 36, 38 (3)	31, 33, 34, 35 39, 40 (6)	.....	.....	.....	.....	9
0.020	12	None	25, 26, 27, 28, 29 30, 31, 32, 33, 34 35, 36 (12)	.....	.....	.....	.....	.....	.....	12
0.022	14	None	35 (1)	29, 30, 31, 32, 33 34, 36, 37, 38, 39 40, 41, 42 (13)	.....	.....	.....	.....	.....	14
0.027	14	None	None	29, 30, 31, 32, 33 34, 35, 36, 37, 38 39, 40, 41, 42 (14)	.....	.....	.....	.....	.....	14
0.020	3	None	None	None	7, 8, 9 (3)^a	.....	.....	.....	.....	3
0.013	3	None	11 (1)	6, 7 (2)	.....	.....	.....	.....	.....	3
0.133	3	None	None	None	None	None	None	None	113 (1)	1
0.018	3	None	None	122, 423, 424 (3)	.....	.....	.....	.....	.....	3
.....	84	None	30	37	10	2	2	None	1	82

ater than all other sheets.

pared to non-copper-bearing metal of substantially the same general composition. from which superiority we may truly anticipate a marked increase in the service life for copper-bearing metals under atmospheric exposure of uncoated sheets.

It is interesting to note in this connection that the A and O groups of sheets, the light gage non-copper-bearing Bessemer and open-hearth metals, which failed first at Pittsburgh, have also failed first at Fort Sheridan, which would indicate that the two different atmospheric conditions have shown substantially the same general tendencies, only with varying rates of corrosion.

TABLE XIV.—AVERAGE COMPOSITIONS OF GROUPS OF SHEETS OF PITTSBURGH TESTS THAT HAVE COMPLETELY FAILED.
SHEETS EXPOSED DECEMBER 12, 1916.

Group.	Type Designation.	Carbon, per cent.	Manganese, per cent.	Phosphorus, per cent.	Sulfur, per cent.	Silicon, per cent.	Copper, per cent.
A 31-47	No. 22 Gage Bessemer Steel, Series A.	0.038	0.386	0.089	0.040	0.007	0.014
C 11-14 C 32-35	No. 22 Gage Copper-Bearing Pure Iron, Series A.	0.015	0.028	0.006	0.036	0.003	0.190
C 20-22	No. 22 Gage Copper-Bearing Pure Iron, Series A.	0.01	0.028	0.002	0.027	0.002	0.139
D 30-40	No. 22 Gage Low-Copper Pure Iron, Series A.	0.020	0.026	0.004	0.022	0.002	0.024
E 25-36	No. 22 Gage Puddled Iron, Series A.	0.033	0.034	0.114	0.021	0.134	0.283
O 25-36	No. 22 Gage Open-Hearth Steel, Series A.	0.121	0.536	0.008	0.030	0.249	0.020
S 29-42	No. 22 Gage Low-Copper Pure Iron, Series B, American Rolling Mill Co.	0.020	0.023	0.006	0.022	0.004	0.022
T 29-42	No. 22 Gage Copper-Bearing Steel, Series B, Newport Rolling Mill Co.	0.083	0.313	0.009	0.020	0.005	0.227
U 29-42	No. 22 Gage Copper-Bearing Pure Iron, Series B, Allegheny Steel Co.	0.017	0.074	0.008	0.037	0.005	0.260
V 29-42	No. 22 Gage Copper-Bearing Pure Iron, Series B, Whittaker-Glessner Co.	0.018	0.051	0.007	0.021	0.005	0.304
X 29-42	No. 22 Gage Low-Copper Pure Iron, Series B, Inland Steel Co.	0.021	0.055	0.007	0.031	0.004	0.027
Y 7-9[a]	No. 22 Gage Low-Copper Wrought Iron, Series B, Youngstown Sheet and Tube Co.	0.03	0.055	0.139	0.021	0.218	0.020
Z 6, 7, 11	No. 22 Gage Bessemer Steel, Series B, Youngstown Sheet and Tube Co.	0.055	0.37	0.119	0.048	0.003	0.013
Z 422, 423, 424	No. 22 Gage Open-Hearth Steel, Series B, Youngstown Sheet and Tube Co.	0.10	0.32	0.069	0.044	0.002	0.018
AA 21-30 AA 50-56[b]	No. 16 Gage Bessemer Steel, Series A. " " " " "	0.043	0.419	0.083	0.042	0.004	0.012
SS 29-42	No. 16 Gage Low-Copper Pure Iron, Series B, A. R. M. Co.	0.017	0.021	0.006	0.021	0.006	0.025
ZZ 8, 10, 14	No. 16 Gage Bessemer Steel, Series B, Youngstown Sheet and Tube Co.	0.07	0.40	0.097	0.037	0.008	0.013

[a] Y Sheets exposed June 2, 1917.
[b] AA sheets 50-56 sand blasted.

Table XIV is presented as showing in condensed form the average composition of groups of sheets which have completely failed at the Pittsburgh location. No further detail record for these sheets will appear in future reports.

The third meeting of the sub-committee was held at Philadelphia on May 4, 1921, at which time the report of the sub-committee was considered and unanimously approved.

Respectfully submitted on behalf of the sub-committee,

J. H. GIBBONEY,
Chairman.

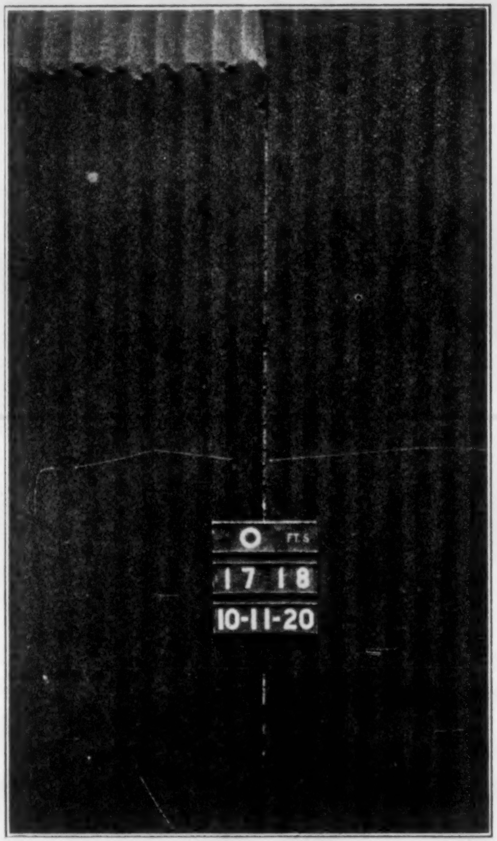

FIG. 1.—FORT SHERIDAN TESTS.
NO. 22 GAGE LOW-COPPER OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
O 17...	0.11	0.52	0.009	0.029	0.21	0.026	None
O 18...	0.11	0.53	0.005	0.029	....	0.018	None

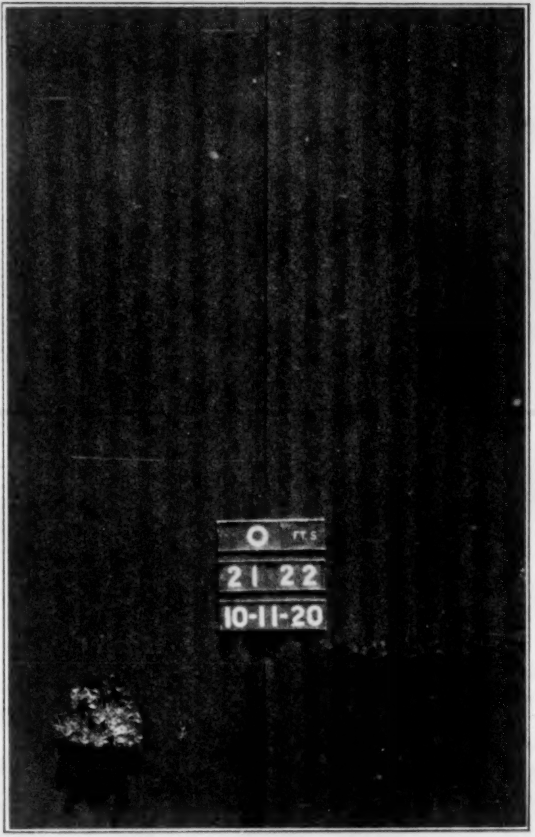

FIG. 2.—FORT SHERIDAN TESTS.
NO. 22 GAGE LOW-COPPER OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
O 21...	0.11	0.57	0.009	0.031	0.236	0.022	....
O 22...	0.11	0.57	0.010	0.034	0.238	0.026	....

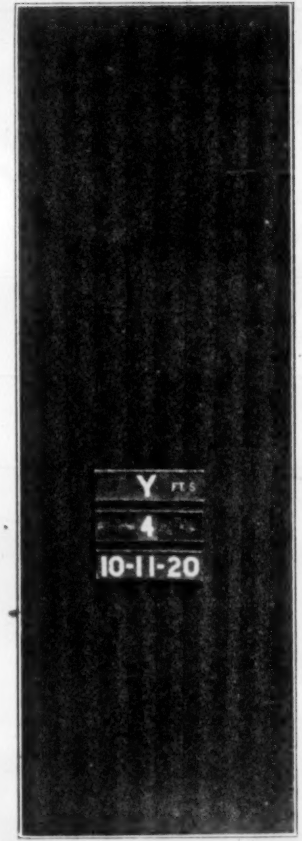

FIG. 3.—FORT SHERIDAN TESTS.
NO. 22 GAGE LOW-COPPER WROUGHT IRON—SERIES B.
YOUNGSTOWN SHEET AND TUBE CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
Y 4....	0.03	0.06	0.133	0.020	0.19	0.020	....

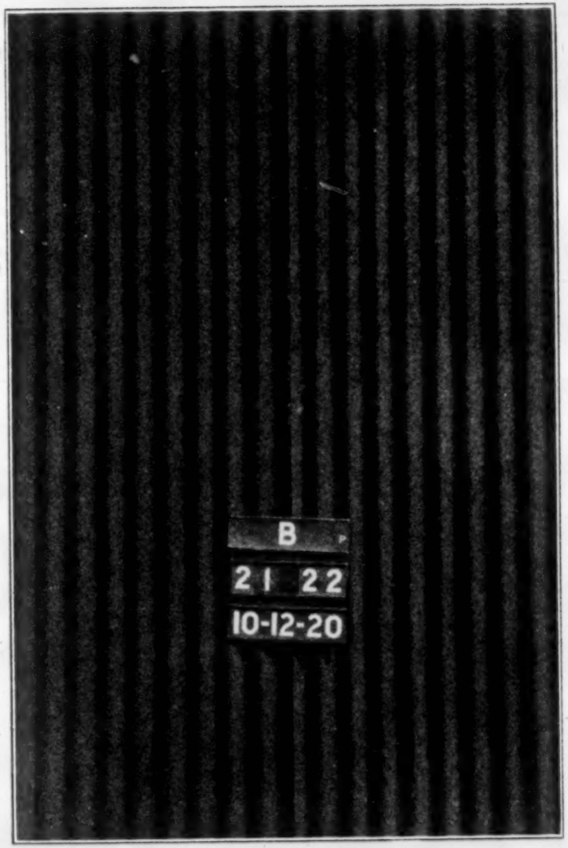

FIG. 4.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
B 21...	0.07	0.22	0.009	.047	0.003	0.173	....
B 22...	0.06	0.22	0.004	0.046	0.003	0.171	....

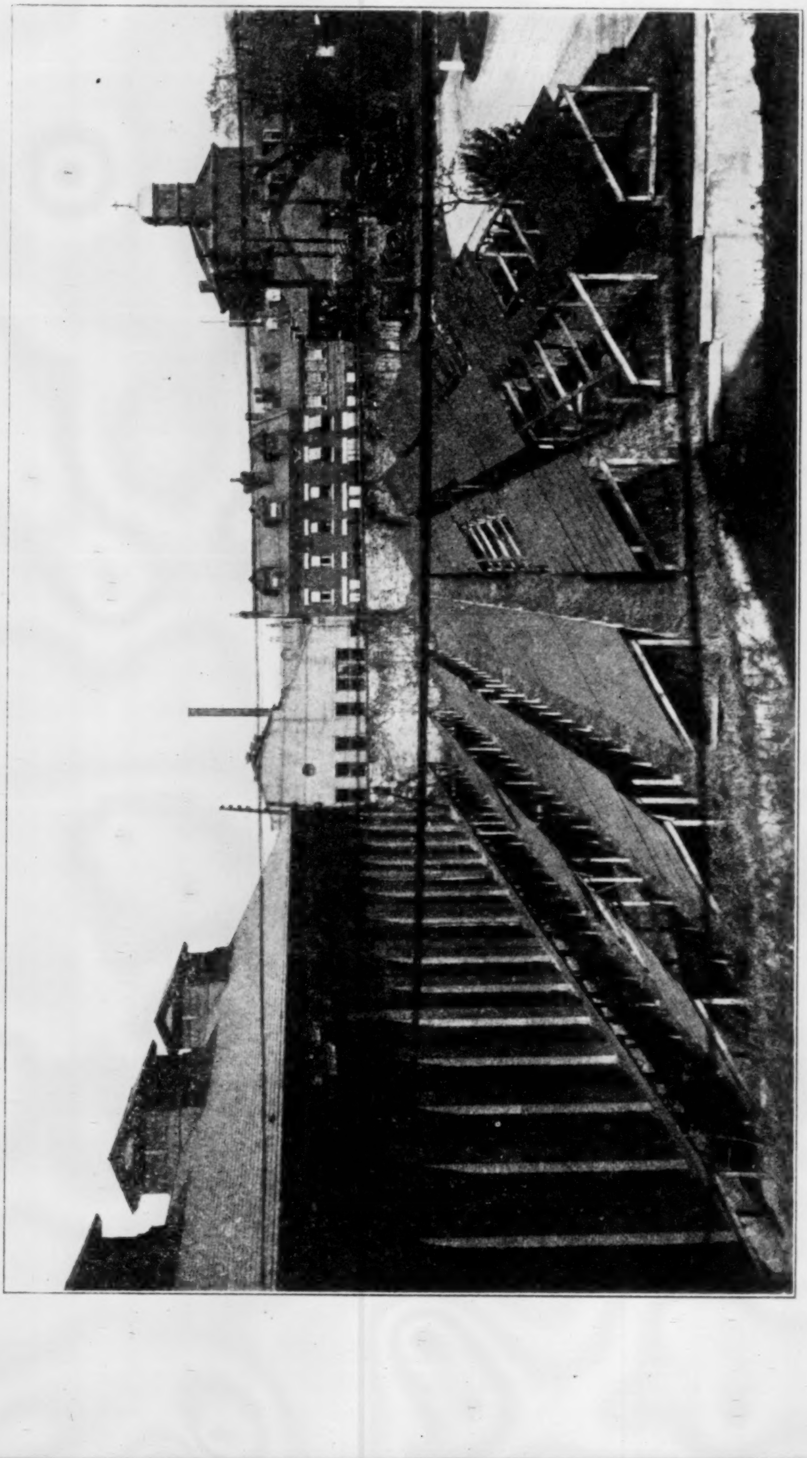

FIG. 5.—PITTSBURGH TEST RACK, SHEETS EXPOSED DECEMBER 12, 1916. PHOTOGRAPHED OCTOBER 12, 1920.

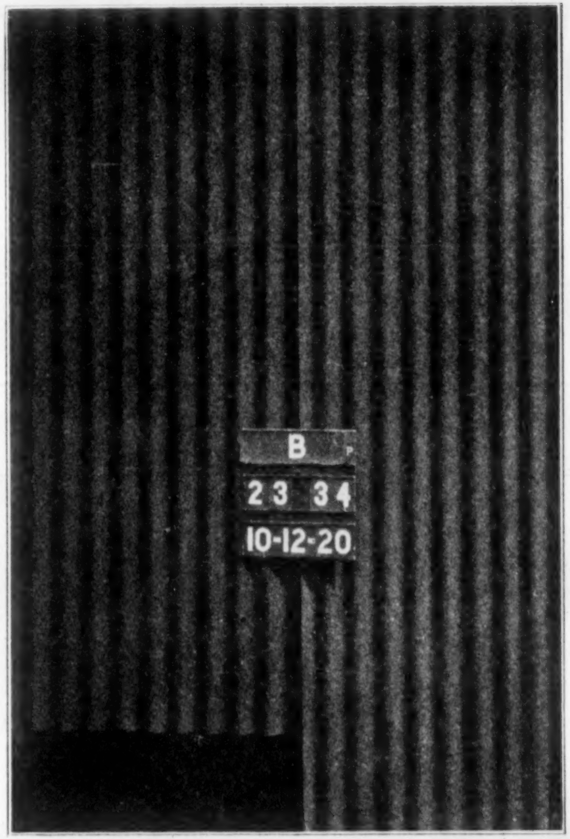

FIG. 6.—PITTSBURGH TESTS.
No. 22 GAGE OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
B 23 . . .	0.07	0.22	0.003	0.040	0.003	0.190	. . .
B 34 . . .	0.05	0.40	0.025	0.055	0.009	0.21	0.075

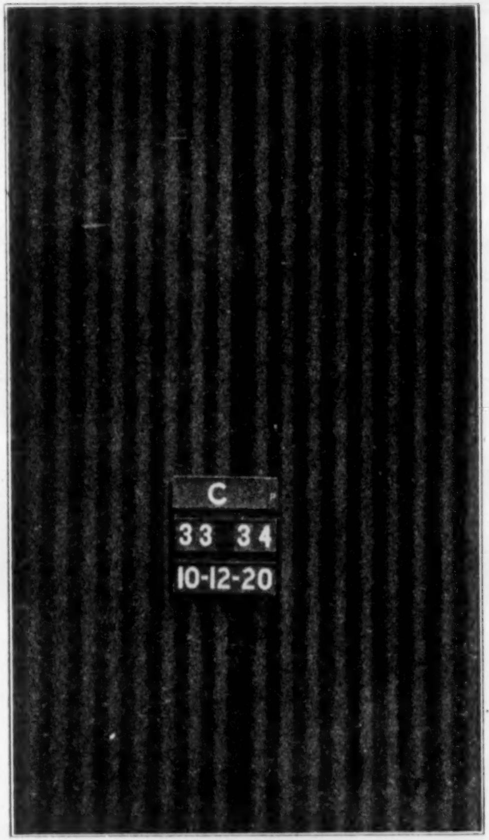

FIG. 7.—PITTSBURGH TESTS.
No. 22 GAGE COPPER-BEARING PURE IRON—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
C 33 . . .	0.02	0.02	0.004	0.033	. . . .	0.17	0.012
C 34 . . .	0.02	0.02	0.004	0.031	. . . .	0.17	. . . .

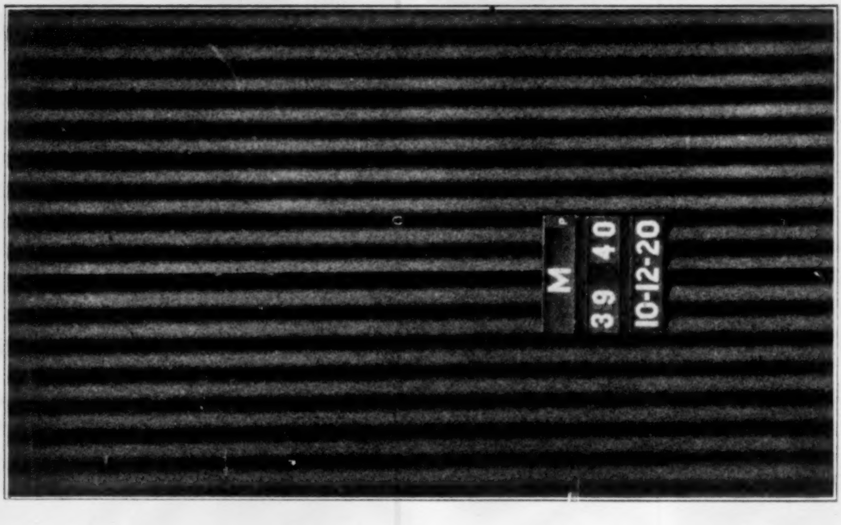

FIG. 8.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 39...	0.095	0.61	0.025	0.039	0.005	0.19	None
M 40...	0.06	0.39	0.015	0.035	0.009	0.19	None

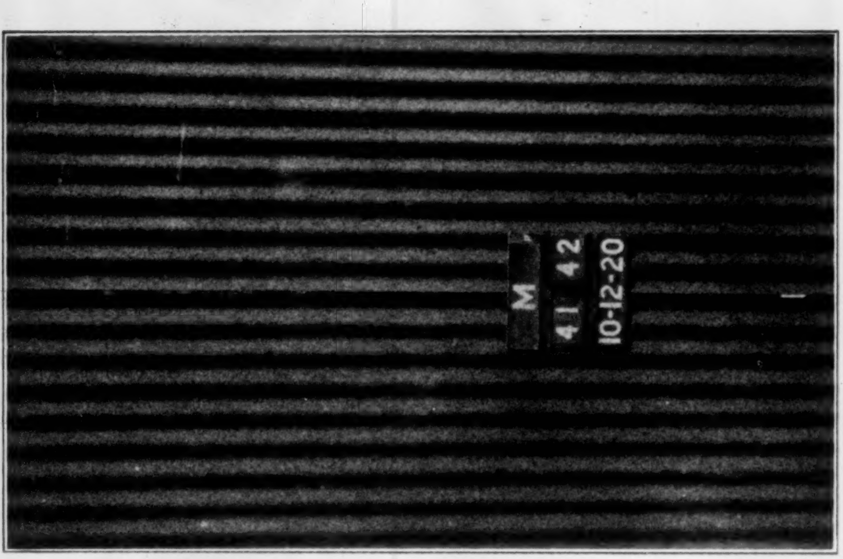

FIG. 9.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 41...	0.075	0.40	0.017	0.040	0.005	0.20	None
M 42...	0.085	0.42	0.015	0.040	0.006	0.20	None

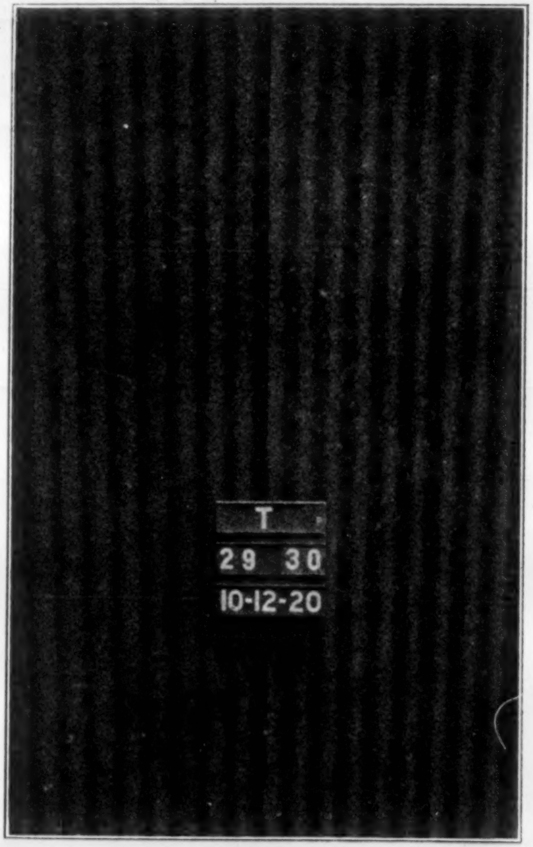

Fig. 10.—Pittsburgh Tests.
No. 22 Gage Copper-Bearing Steel—Series B.
Newport Rolling Mill Co.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
T 29...	0.085	0.294	0.007	0.018	0.009	0.216	None
T 30...	0.103	0.305	0.010	0.019	....	0.219	None

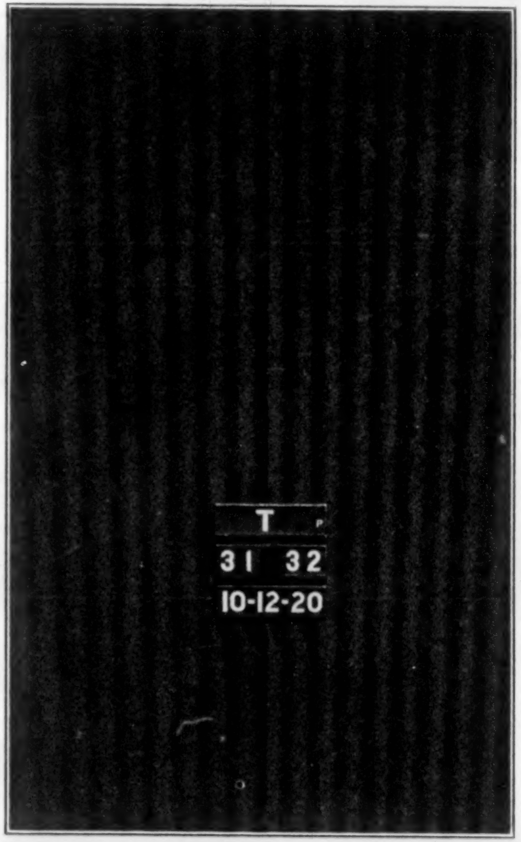

Fig. 11.—Pittsburgh Tests.
No. 22 Gage Copper-Bearing Steel—Series B.
Newport Rolling Mill Co.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
T 31...	0.091	0.299	0.009	0.019	....	0.209	None
T 32...	0.10	0.32	0.006	0.025	0.001	0.226	None

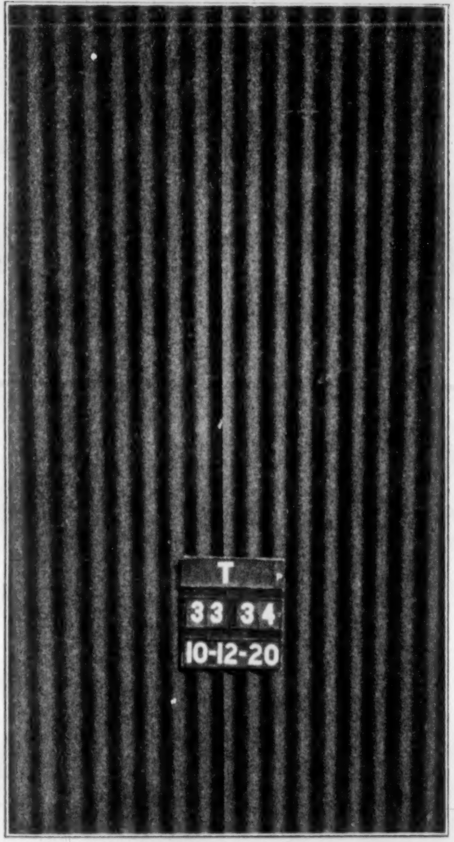

FIG. 12.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING STEEL—SERIES B.
NEWPORT ROLLING MILL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni
T 33...	0.10	0.32	0.006	0.022	....	0.228	None
T 34...	0.10	0.34	0.006	0.024	....	0.212	None

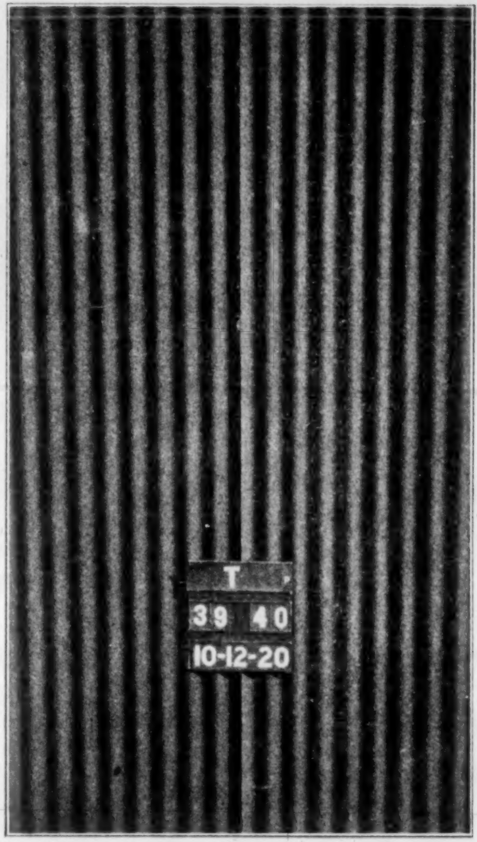

FIG. 13.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING OPEN-HEARTH STEEL—SERIES B.
NEWPORT ROLLING MILL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
T 39...	0.075	0.32	0.008	0.024	Trace	0.19	None
T 40...	0.085	0.31	0.009	0.025	Trace	0.20	None

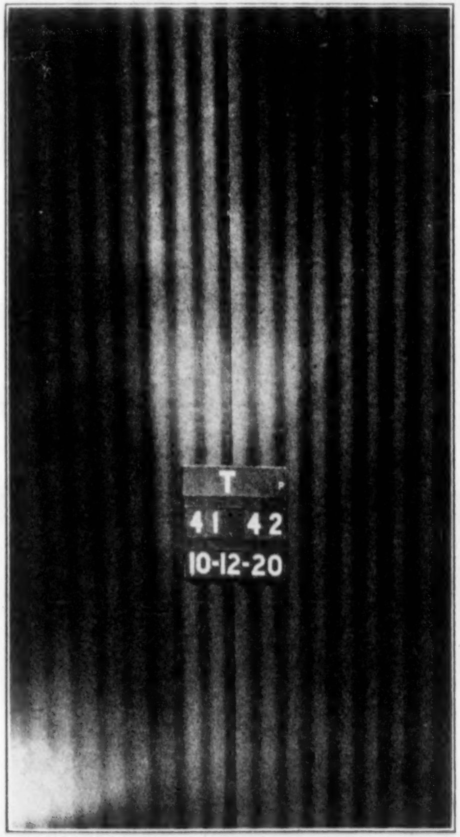

FIG. 14.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING STEEL—SERIES B.
NEWPORT ROLLING MILL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
T 41...	0.09	0.31	0.009	0.023	Trace	0.20	None
T 42...	0.085	0.31	0.008	0.024	Trace	0.23	None

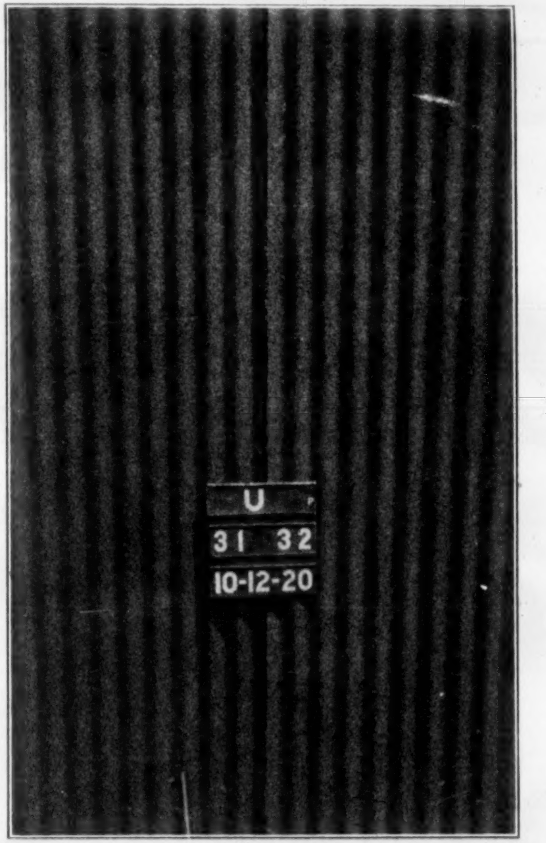

FIG. 15.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 31...	0.013	0.066	0.007	0.039	0.002	0.268	0.010
U 32...	0.014	0.066	0.007	0.034	....	0.249	0.015

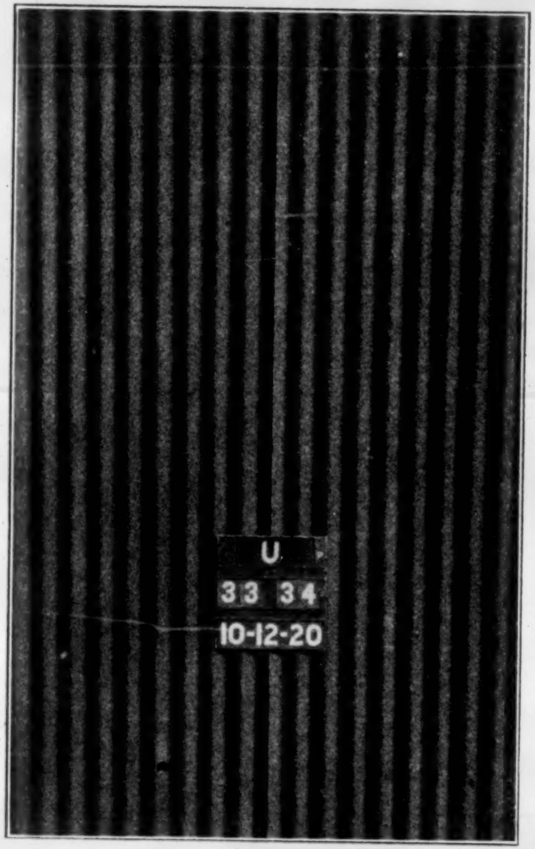

FIG. 16.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 33...	0.014	0.066	0.007	0.035	....	0.262	0.013
U 34...	0.02	0.063	0.007	0.036	0.002	0.25	None

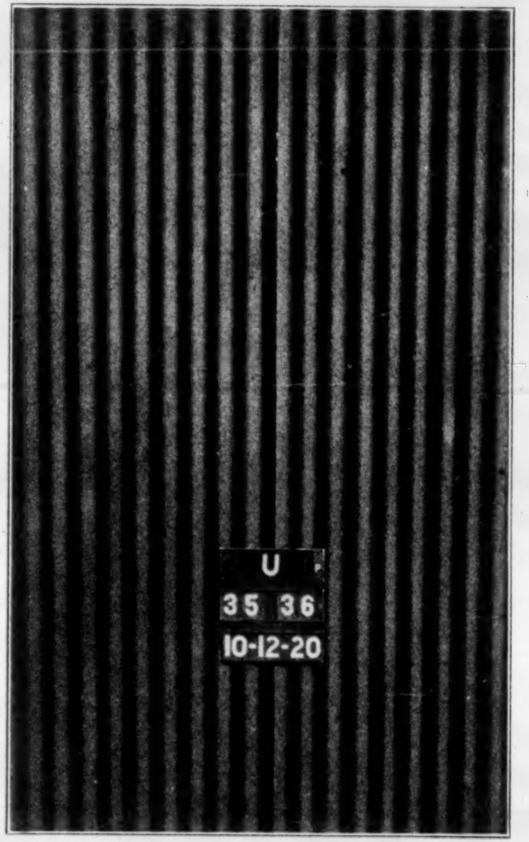

FIG. 17.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 35...	0.02	0.063	0.007	0.036	....	0.210	None
U 36...	0.02	0.072	0.007	0.048	0.001	0.246	None

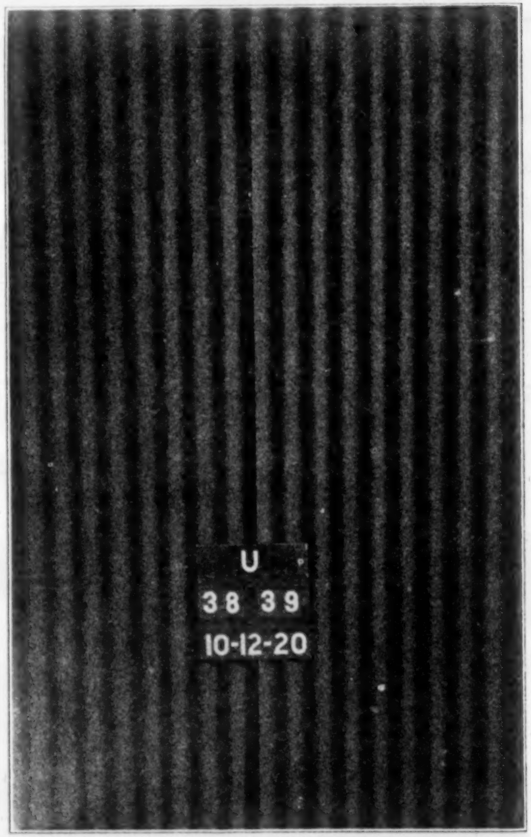

FIG. 18.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 38...	0.01	0.07	0.007	0.035	Trace	0.28	None
U 39...	0.005	0.08	0.006	0.034	Trace..	0.27	None

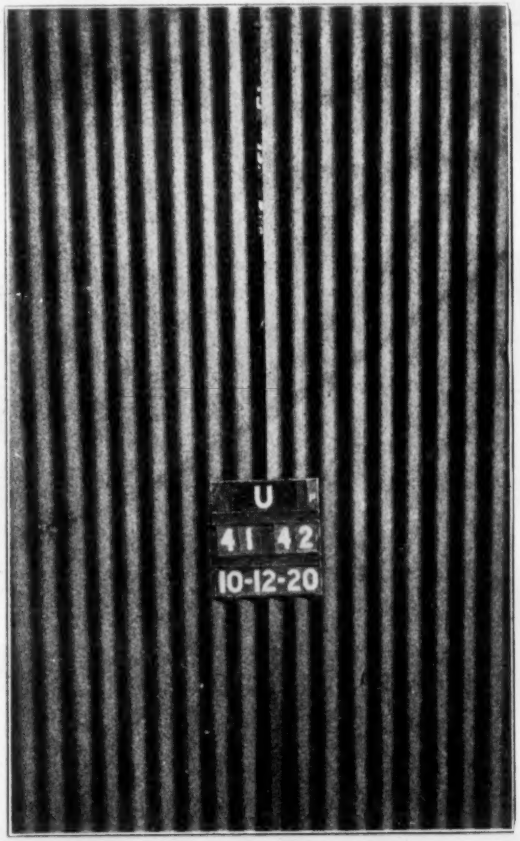

FIG. 19—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 41...	0.005	0.07	0.008	0.037	Trace..	0.28	None
U 42...	0.01	0.07	0.008	0.036	Trace	0.28	None

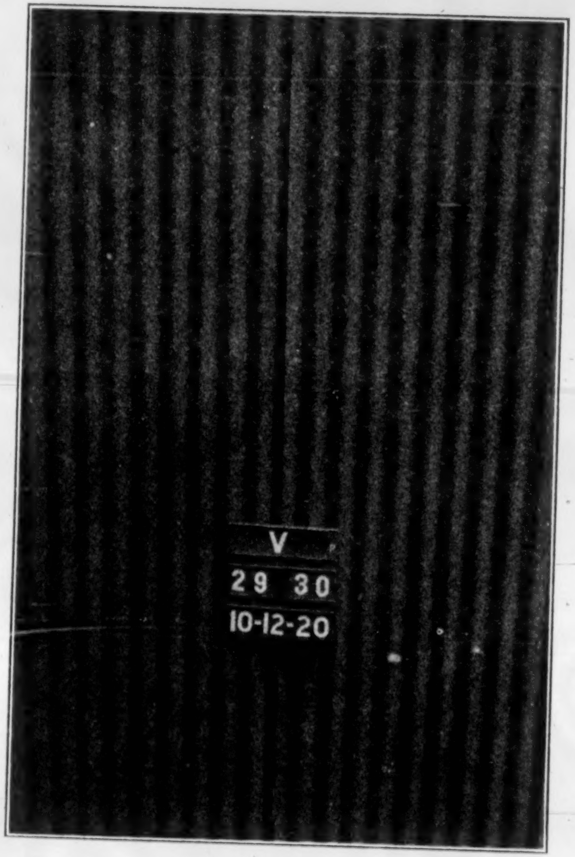

FIG. 20.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
WHITAKER-GLESSNER CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
V 29...	0.021	0.036	0.006	0.017	....	0.312	None
V 30...	0.02	0.036	0.005	0.016	....	0.296	None

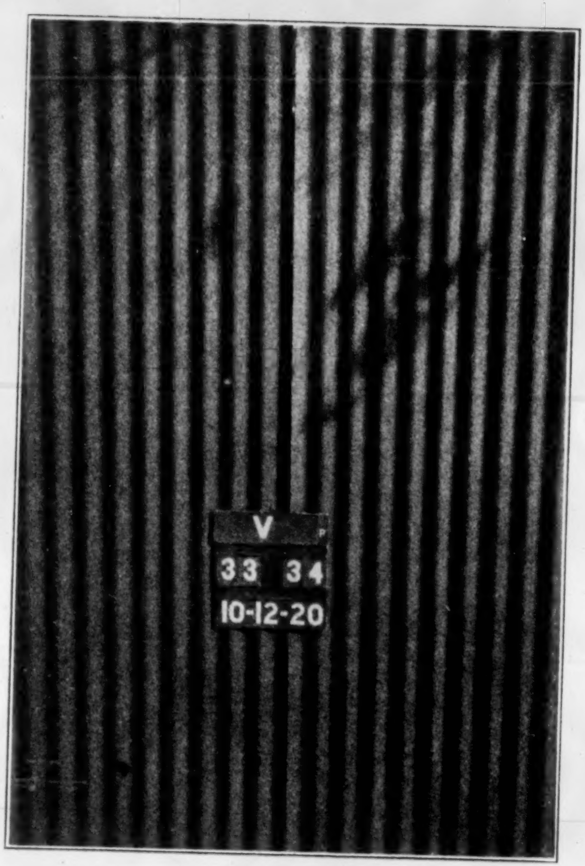

FIG. 21.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
WHITAKER-GLESSNER CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
V 33...	0.02	0.036	0.005	0.026	....	0.296	None
V 34...	0.02	0.036	0.004	0.027	....	0.286	None

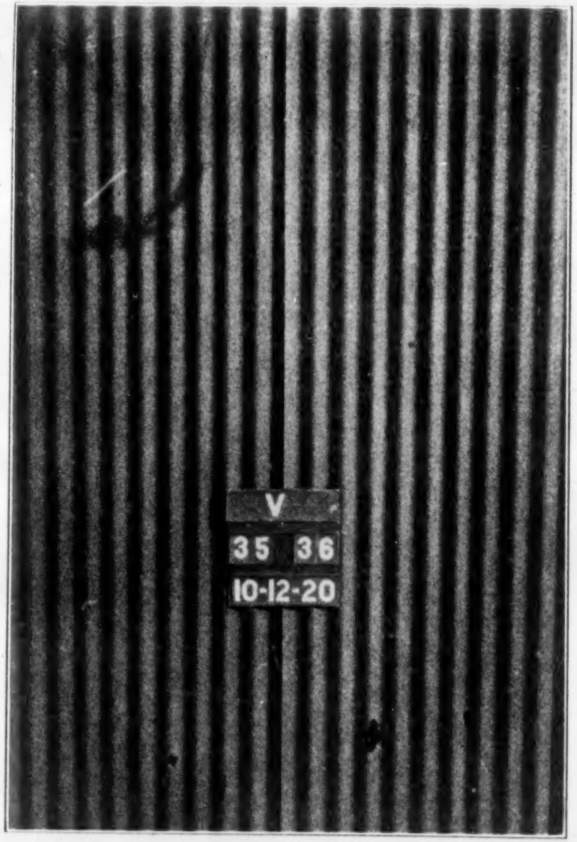

FIG. 22.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
WHITAKER-GLESSNER CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
V 35...	0.02	0.036	0.004	0.022	0.002	0.285	None
V 36...	0.01	0.06	0.008	0.023	Trace	0.33	None

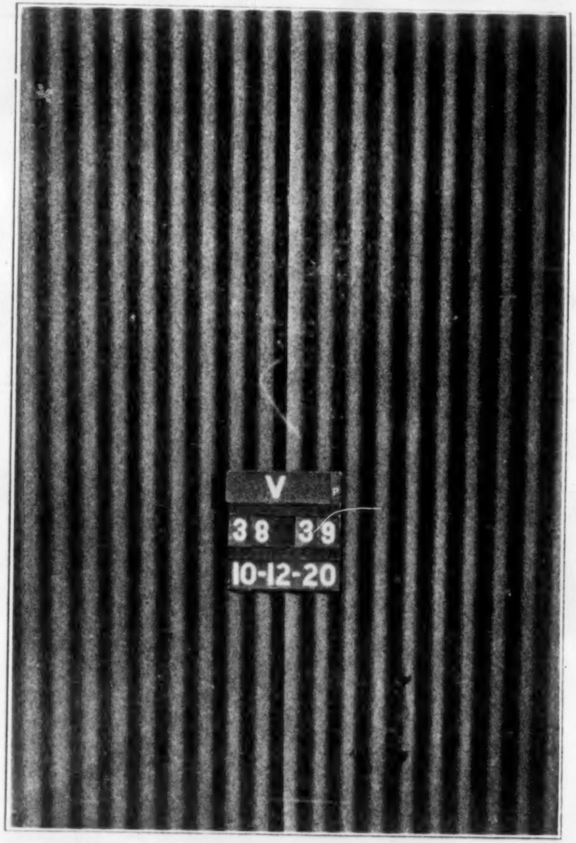

FIG. 23.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
WHITAKER-GLESSNER CO.

Sheet.	C	Mn.	P.	S.	Si.	Cu.	Ni.
V 38...	0.025	0.05	0.007	0.024	Trace	0.31	None
V 39...	0.01	0.05	0.006	0.024	Trace	0.31	None

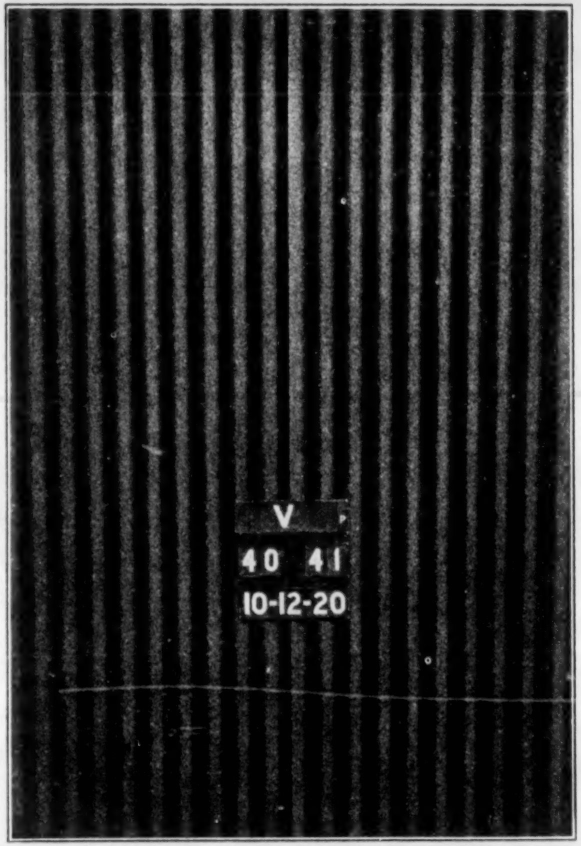

FIG. 24—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
WHITAKER-GLESSNER CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
V 40....	0.01	0.05	0.007	0.025	Trace	0.31	None
V 41...	0.02	0.06	0.007	0.019	Trace	0.28	None

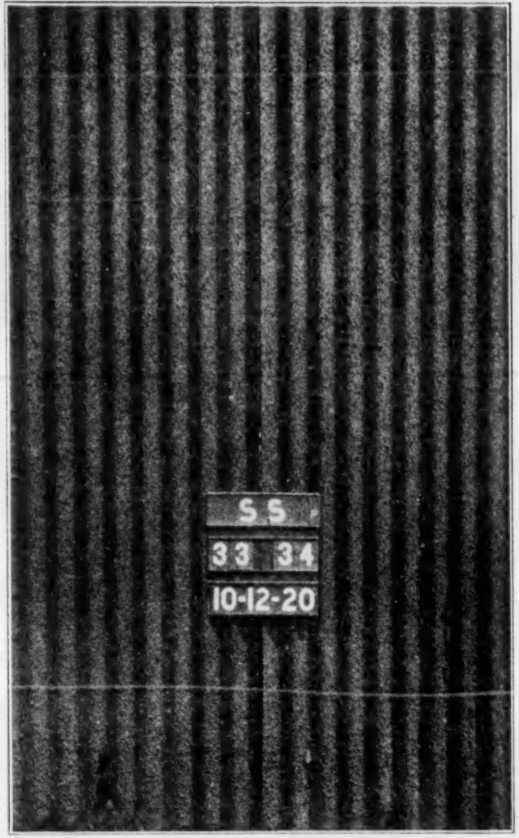

FIG. 25.—PITTSBURGH TESTS.
NO. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
AMERICAN ROLLING MILL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
SS 33..	0.02	0.018	0.003	0.029	....	0.027	None
SS 34..	0.02	0.018	0.004	0.023	0.002	0.020	None

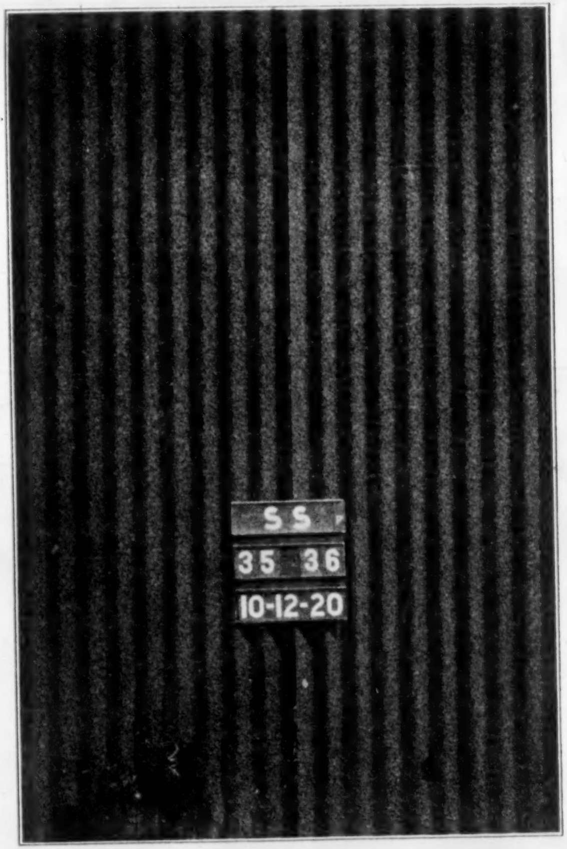

Fig. 26.—Pittsburgh Tests.
No. 16 Gage Low-Copper Pure Iron—Series B.
American Rolling Mill Co.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
SS 35. .	0.02	0.02	0.007	0.028	Trace	0.03	None
SS 36. .	0.005	0.02	0.005	0.025	Trace	0.022	None

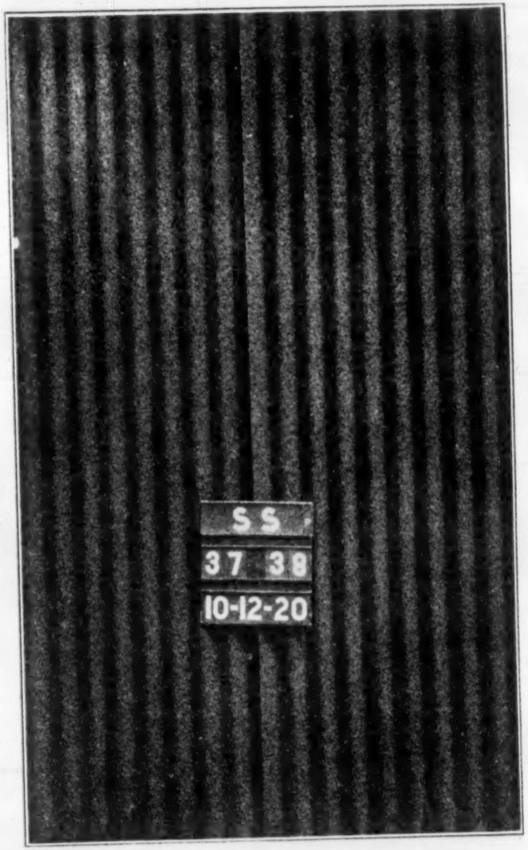

Fig. 27.—Pittsburgh Tests.
No. 16 Gage Low-Copper Pure Iron—Series B.
American Rolling Mill Co.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
SS 37. .	0.005	0.02	0.006	0.029	Trace	0.03	None
SS 38. .	0.015	0.02	0.008	0.027	Trace	0.03	None

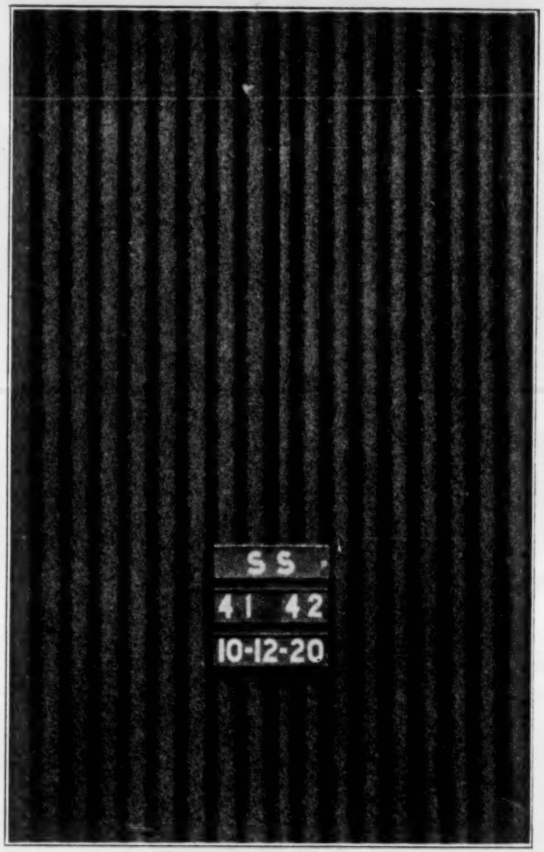

FIG. 28.—PITTSBURGH TESTS.
No. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
AMERICAN ROLLING MILL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
SS 41..	0.03	0.02	0.007	0.022	Trace	0.024	None
SS 42..	0.015	0.02	0.007	0.022	Trace	0.03	None

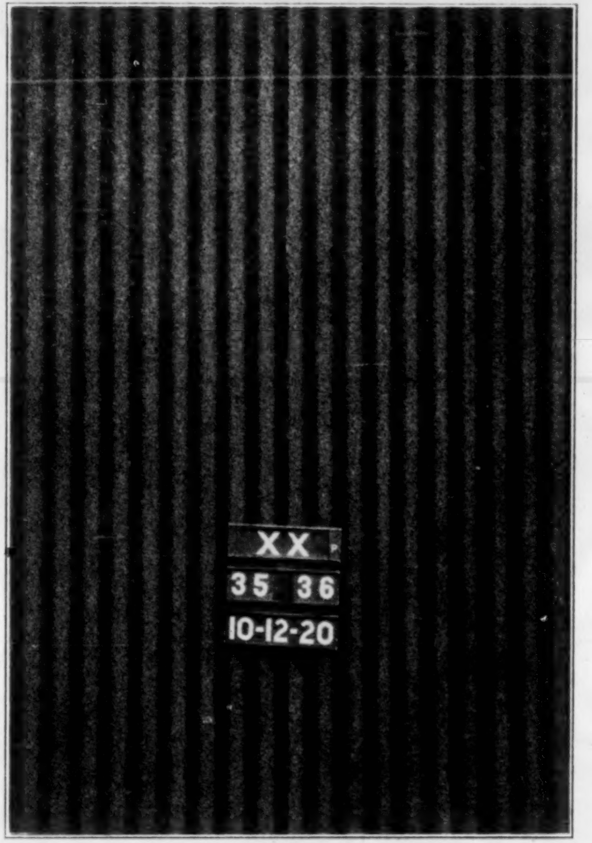

FIG 29.—PITTSBURGH TESTS.
No. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
INLAND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
XX 35.	0.02	0.07	0.008	0.029	Trace	0.04	None
XX 36.	0.02	0.07	0.006	0.032	Trace	0.03	None

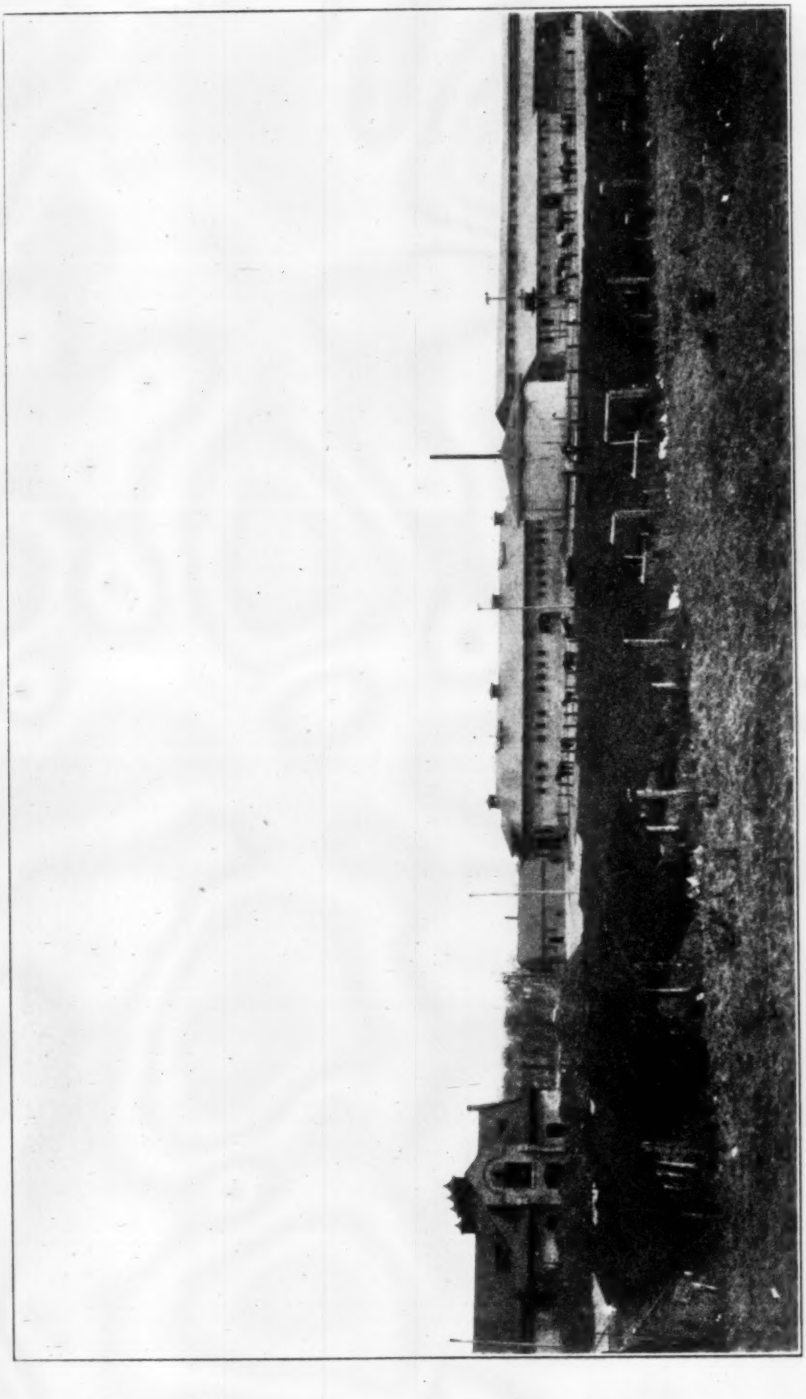

FIG. 30.—FORT SHERIDAN TEST RACK, SHEETS EXPOSED APRIL 9, 1917. PHOTOGRAPHED APRIL 4, 1921.

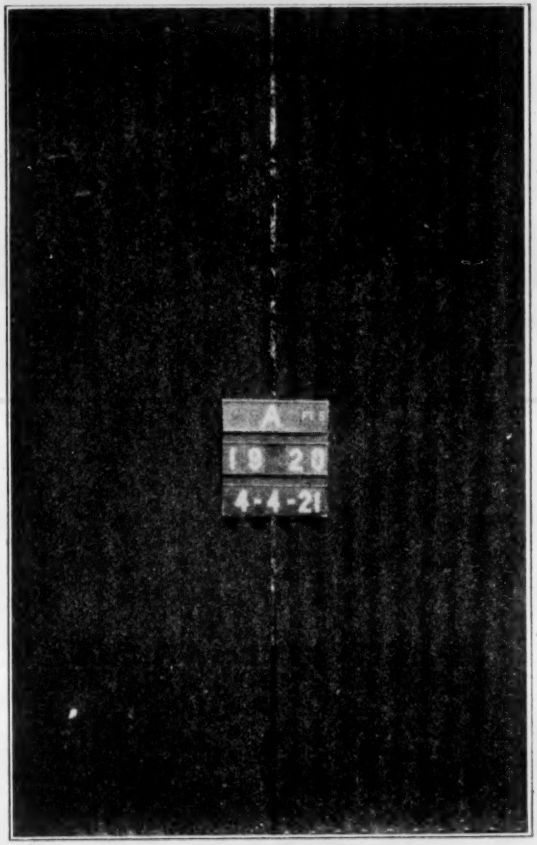

FIG. 31.—FORT SHERIDAN TESTS.
No. 22 GAGE BESSEMER STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
A 19...	0.04	0.41	0.054	0.041	....	0.012	....
A 20...	0.04	0.40	0.101	0.041	....	0.010	....

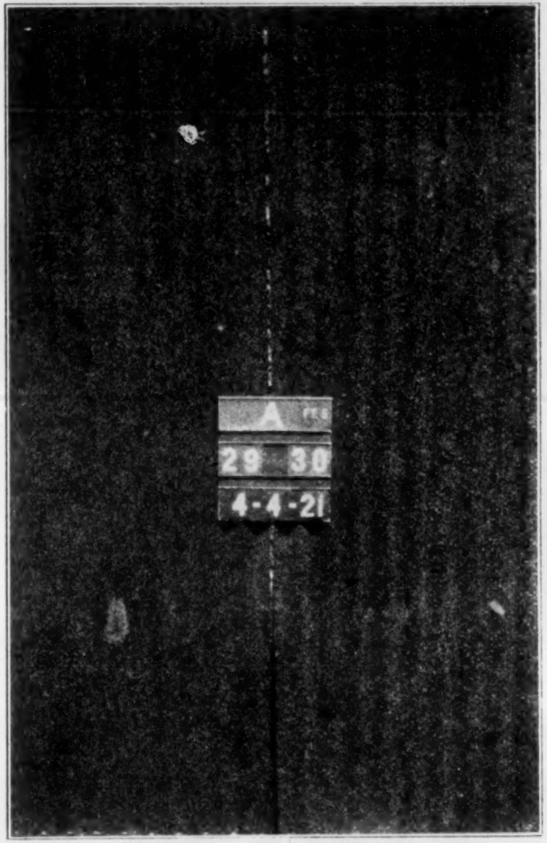

FIG. 32.—FORT SHERIDAN TESTS.
No. 22 GAGE BESSEMER STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
A 29...	0.03	0.39	0.090	0.036	....	0.020	....
A 30...	0.04	0.40	0.087	0.036	....	0.020	....

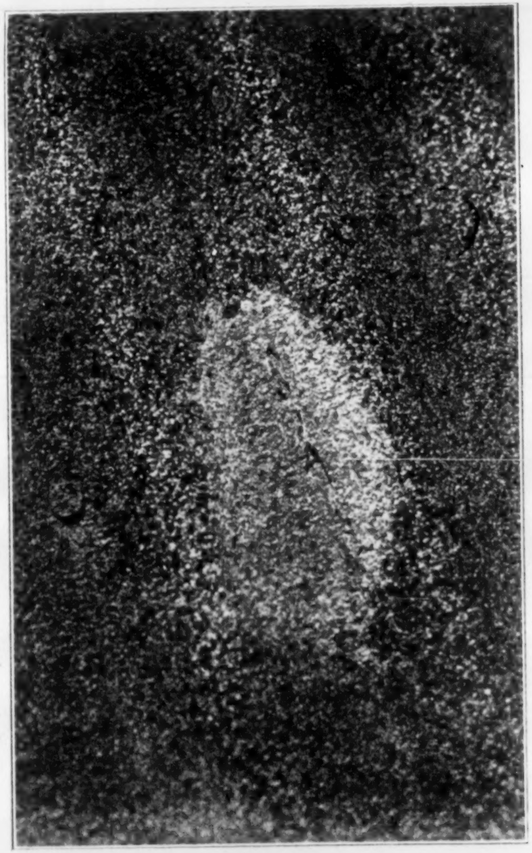

FIG. 33.—FORT SHERIDAN TESTS.
ENLARGED VIEW OF BLISTER AT BOTTOM OF SHEET A 29,
NO. 22 GAGE BESSEMER STEEL—SERIES A.

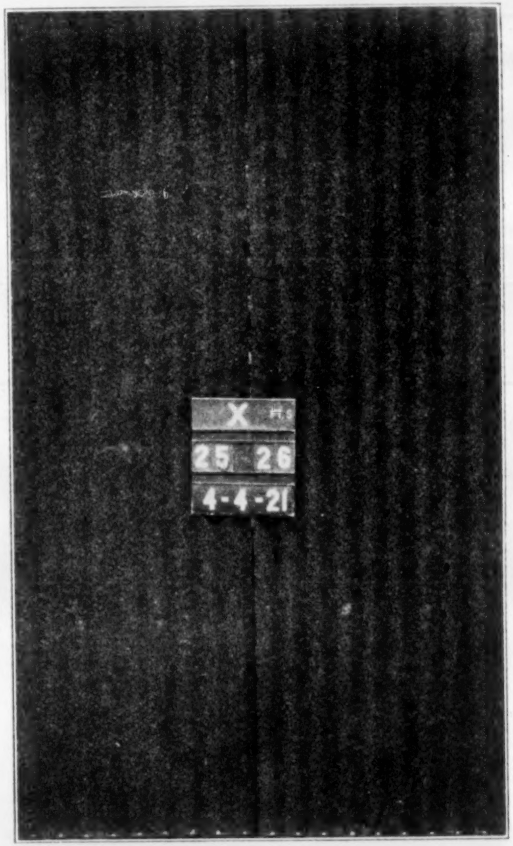

FIG. 34.—FORT SHERIDAN TESTS.
NO. 22 GAGE LOW-COPPER PURE IRON—SERIES B.
INLAND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
X 25...	0.021	0.04	0.005	0.027	0.002	0.026	None
X 26...	0.015	0.038	0.005	0.031	....	0.026	None

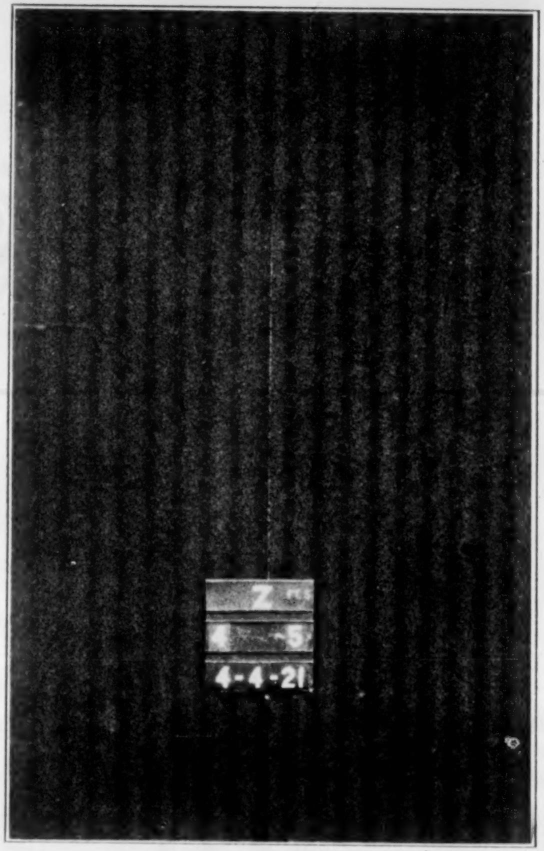

FIG. 35.—FORT SHERIDAN TESTS.
NO. 22 GAGE BESSEMER STEEL (VARYING COPPER CONTENT)—SERIES B.
YOUNGSTOWN SHEET AND TUBE CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
Z 4....	0.07	0.39	0.107	0.047	....	0.012	None
Z 5....	0.06	0.48	0.108	0.045	0.010	0.010	None

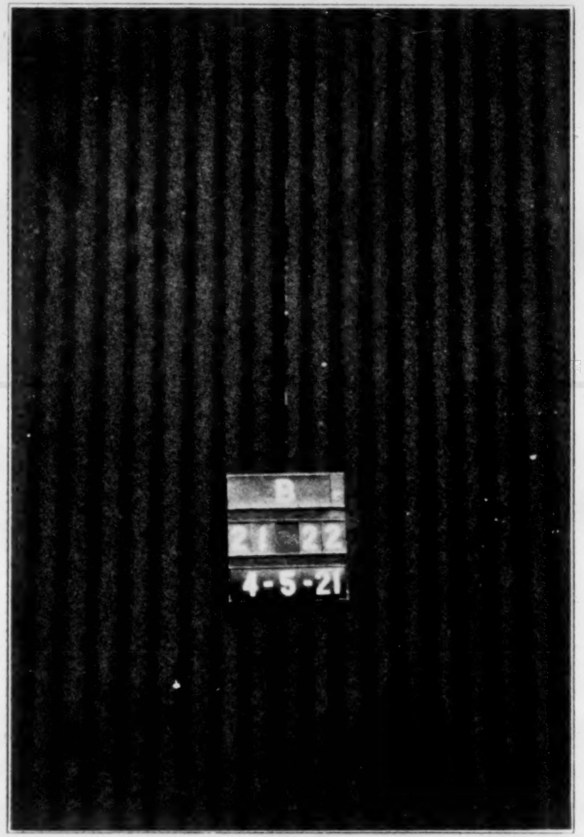

FIG. 36.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
B 21...	0.07	0.22	0.009	0.047	0.003	0.173	....
B 22...	0.06	0.22	0.004	0.046	0.003	0.171	....

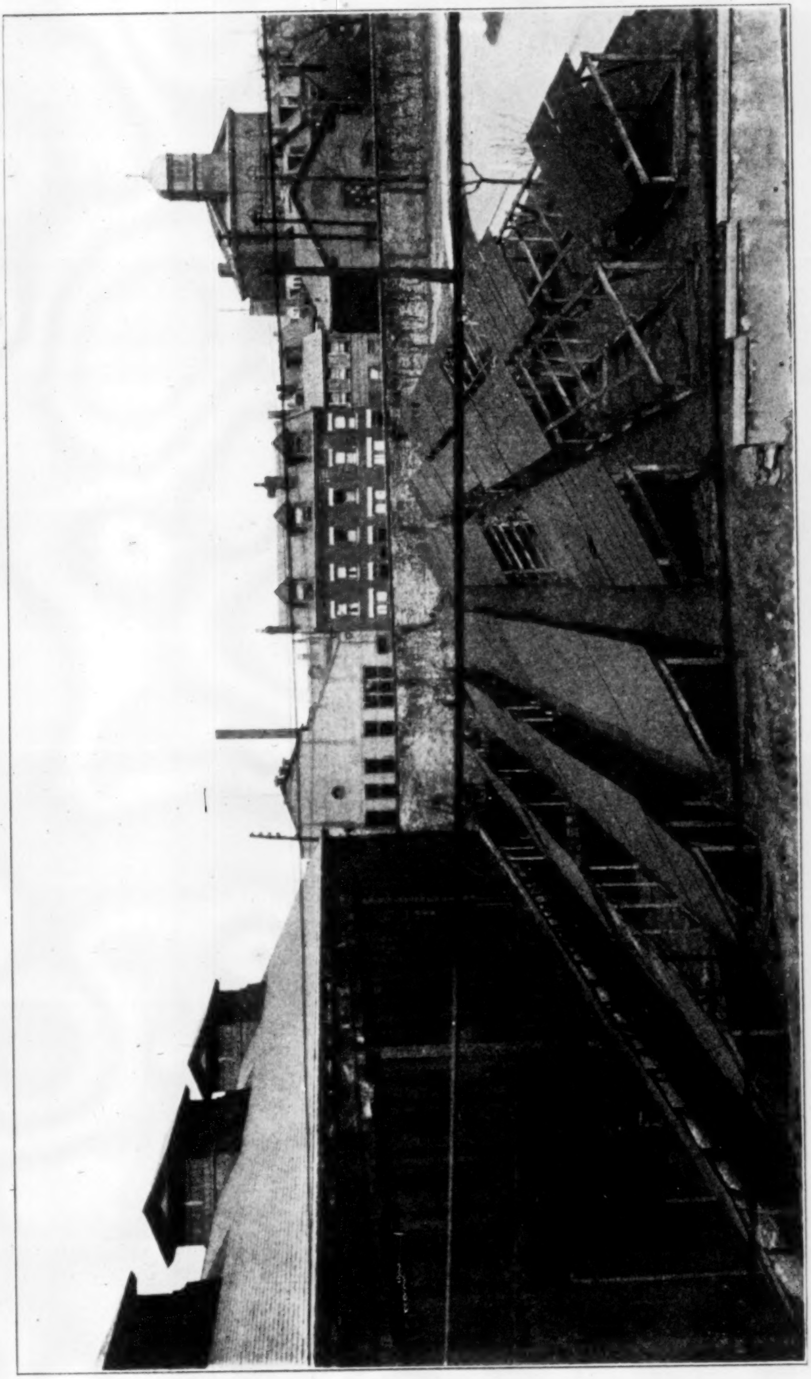

FIG. 37.—PITTSBURGH TEST RACK. SHEETS EXPOSED DECEMBER 12, 1916. PHOTOGRAPHED APRIL 5, 1921.

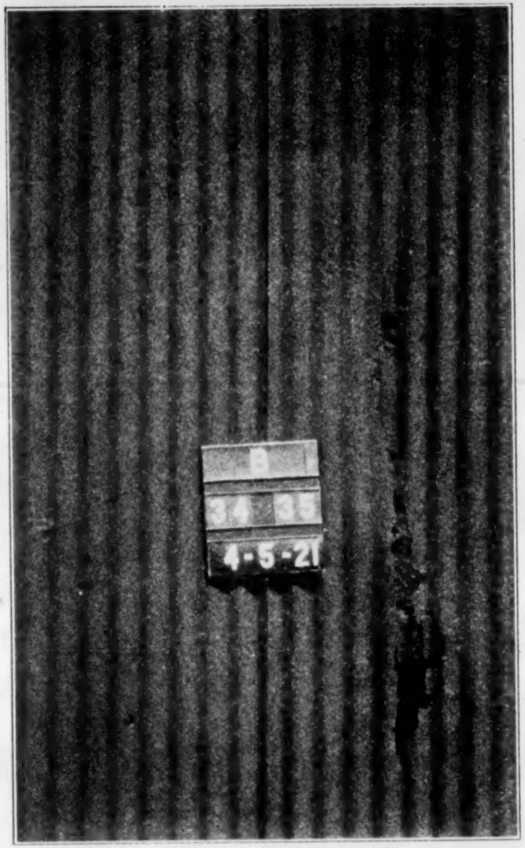

FIG. 38.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
B 34...	0.05	0.40	0.025	0.055	0.009	0.204	0.075
B 35...	0.10	0.40	0.017	0.077	0.042	0.090	0.055

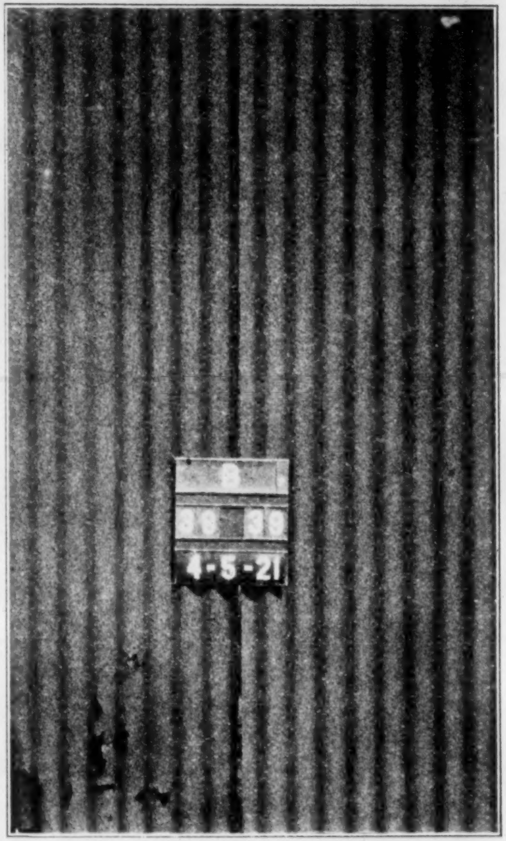

FIG. 39.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
B 38...	0.06	0.36	0.015	0.047	0.033	0.078	0.050
B 39...	0.10	0.40	0.046	0.060	0.025	0.183	0.090

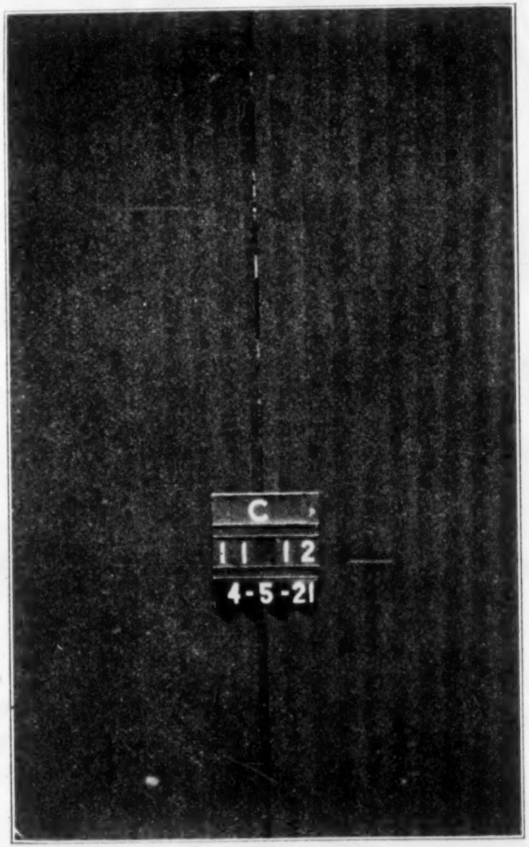

FIG. 40.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
C 11...	0.019	0.035	0.009	0.040	0.004	0.189	....
C 12...	0.036	0.038	0.010	0.043	0.002	0.209	....

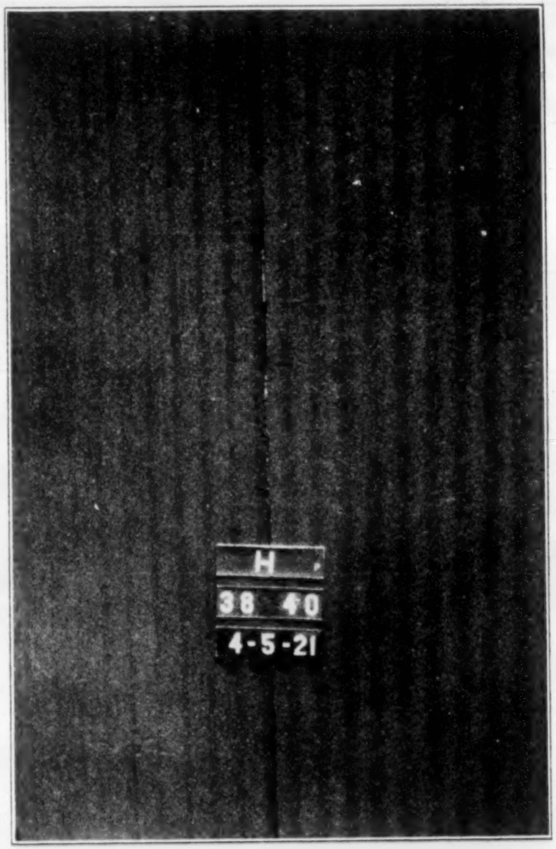

FIG. 41.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING BASIC OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
H 38...	0.06	0.43	0.008	0.021	....	0.24	0.04
H 40...	0.09	0.45	0.055	0.028	....	0.25	Trace

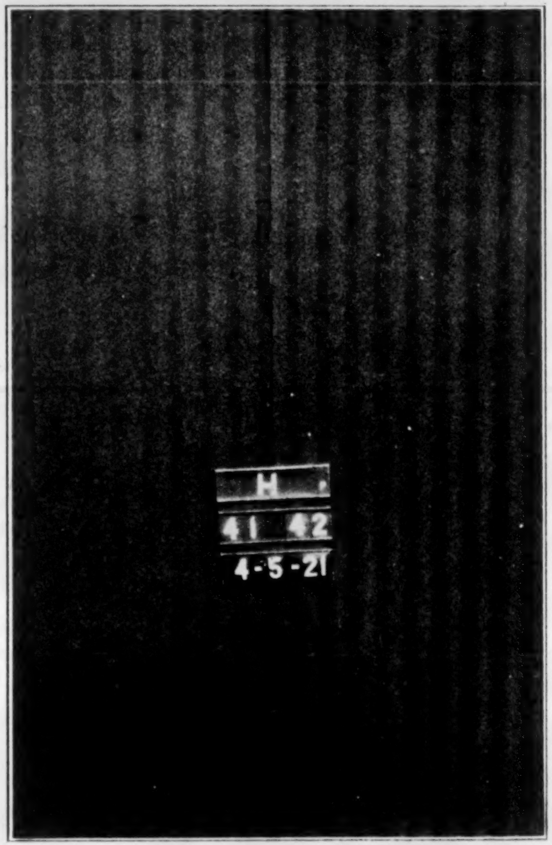

FIG. 42.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING OPEN-HEARTH STEEL
—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
H 41...	0.08	0.44	0.058	0.029	....	0.26	0.01
H 42...	0.09	0.45	0.058	0.030	....	0.26	0.02

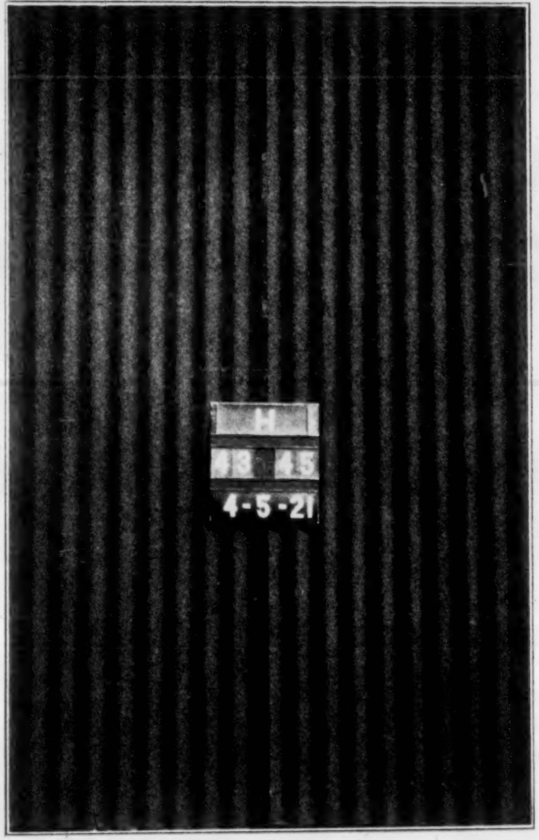

FIG. 43—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING OPEN-HEARTH STEEL
—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
H 43...	0.09	0.44	0.060	0.029	....	0.25	Trace
H 45 ..	0.06	0.38	0.013	0.029	....	0.23	0.030

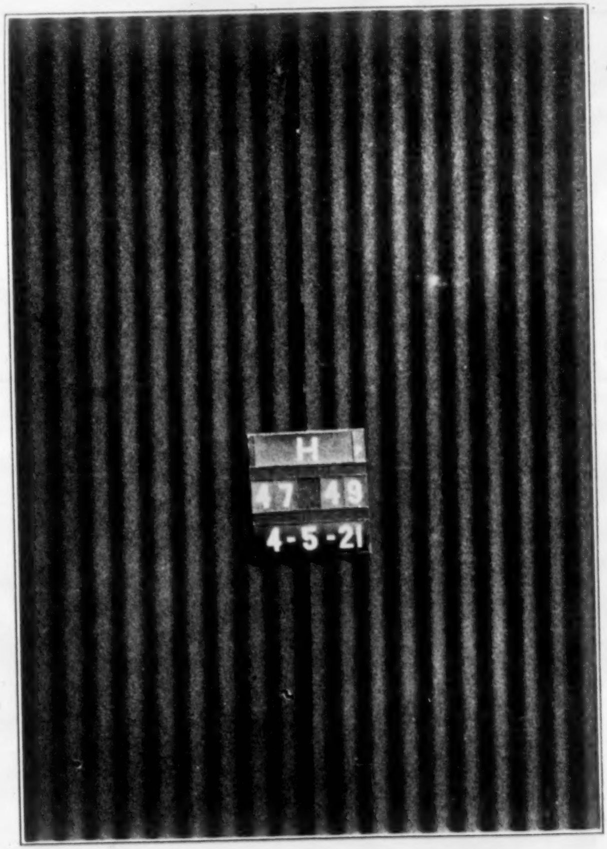

FIG. 44.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING OPEN-HEARTH STEEL
—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
H 47...	0.06	0.38	0.011	0.026	....	0.21	0.025
H 49...	0.05	0.39	0.012	0.024	....	0.23	0.015

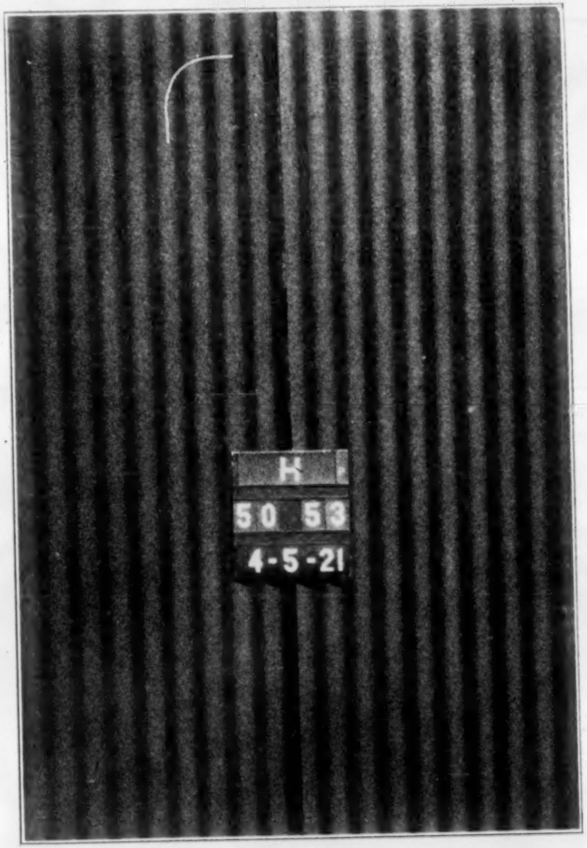

FIG. 45.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING OPEN-HEARTH STEEL
—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
H 50...	0.06	0.39	0.011	0.025	0.004	0.24	0.030
H 53...	0.06	0.38	0.011	0.024	....	0.23	0.030

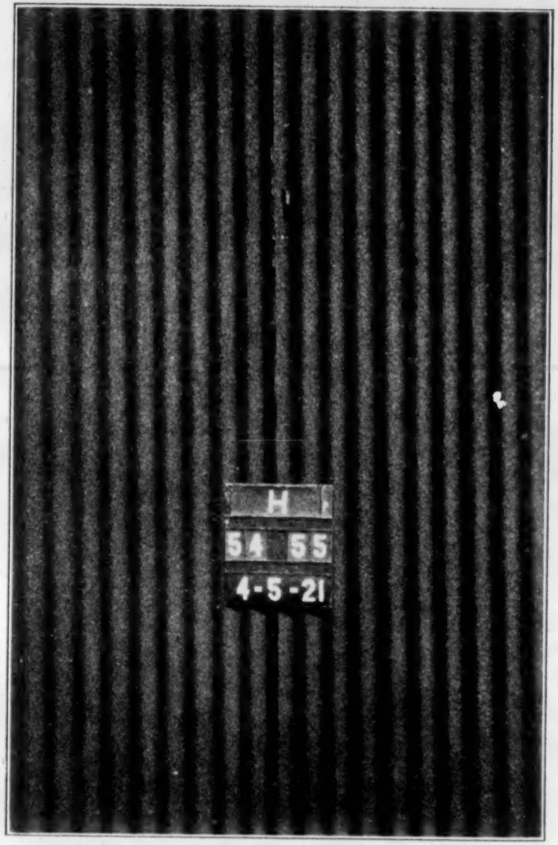

FIG. 46—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING OPEN-HEARTH STEEL
—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
H 54...	0.07	0.39	0.012	0.025	....	0.23	0.030
H 55...	0.06	0.38	0.013	0.024	0.006	0.21	0.030

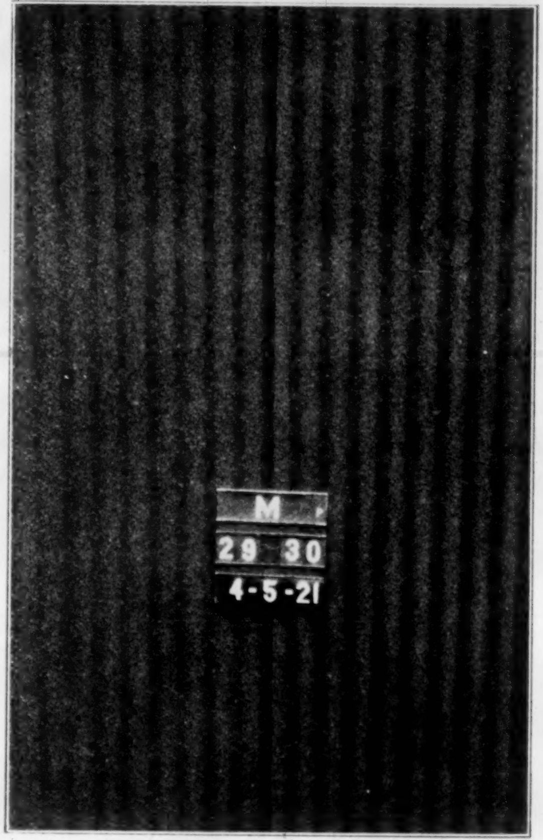

FIG. 47—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 29...	0.095	0.36	0.013	0.041	....	0.176	0.038
M 30...	0.10	0.32	0.007	0.045	0.011	0.176	None

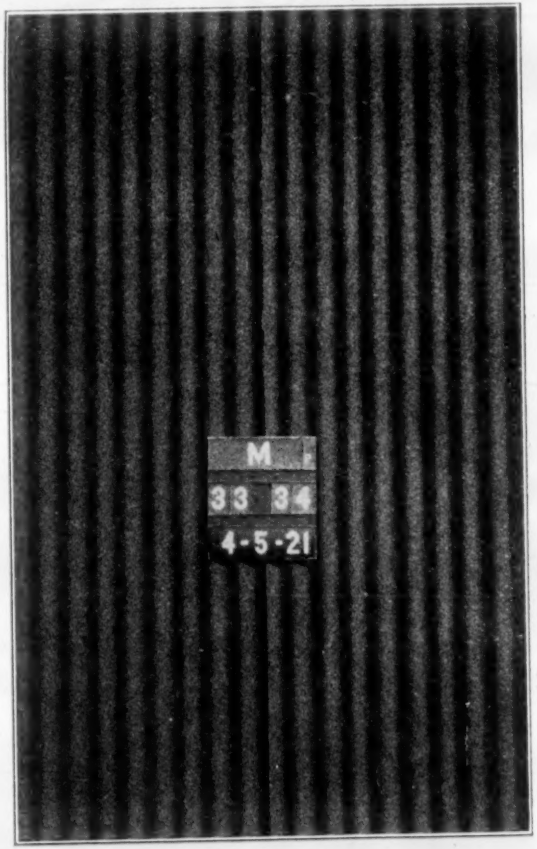

FIG. 48.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 33...	0.10	0.52	0.006	0.034	0.013	0.176	None
M 34...	0.09	0.43	0.006	0.044	....	0.178	None

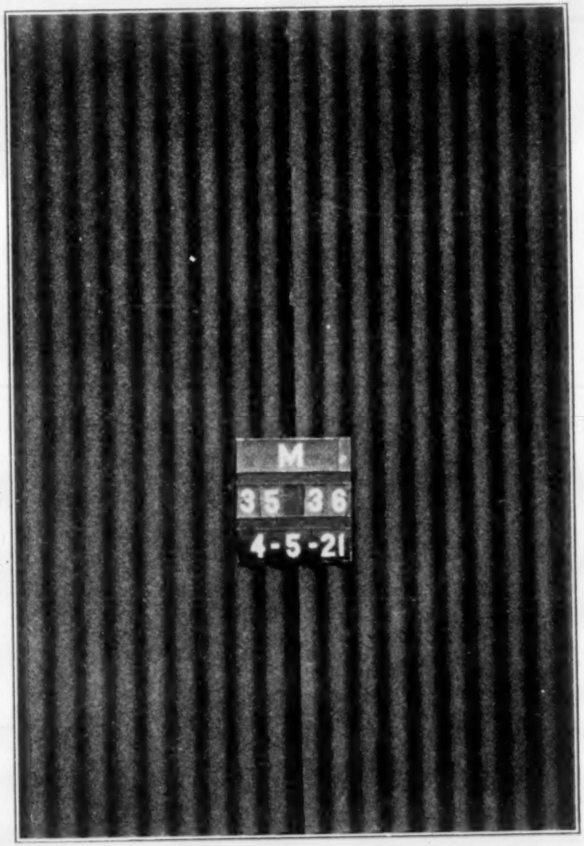

FIG. 49.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 35...	0.10	0.43	0.006	0.046	....	0.172	None
M 36...	0.10	0.52	0.007	0.042	....	0.168	None

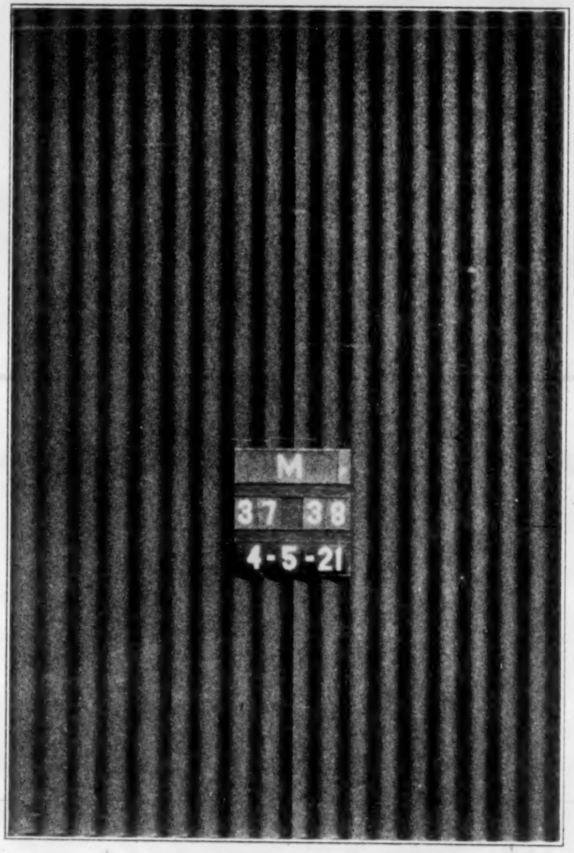

FIG. 50.—PITTSBURGH TESTS.
No. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 37...	0.10	0.59	0.019	0.038	0.011	0.21	None
M 38...	0.085	0.39	0.015	0.036	0.005	0.23	None

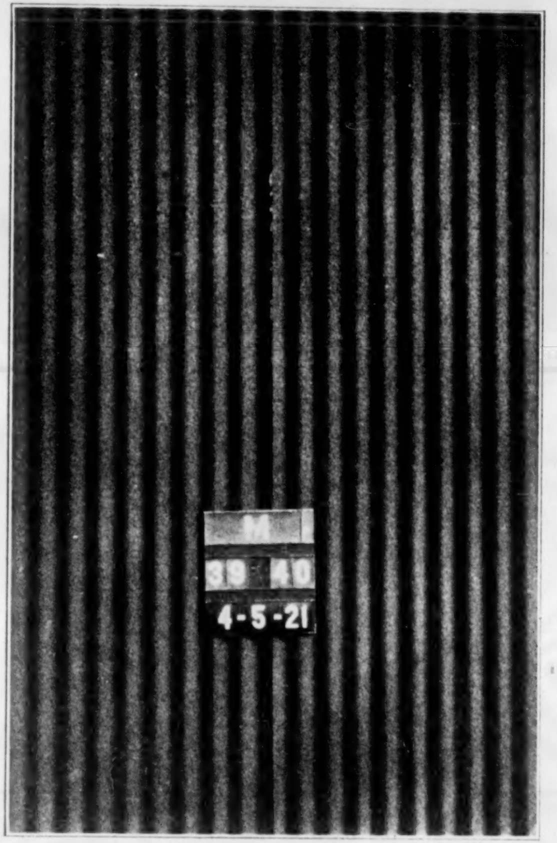

FIG. 51.—PITTSBURGH TESTS.
No. 22 GAGE OPEN-HEARTH STEEL—SERIES B.
ALAN WOOD IRON AND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
M 39...	0.095	0.61	0.025	0.039	0.005	0.19	None
M 40...	0.06	0.39	0.015	0.035	0.009	0.19	None

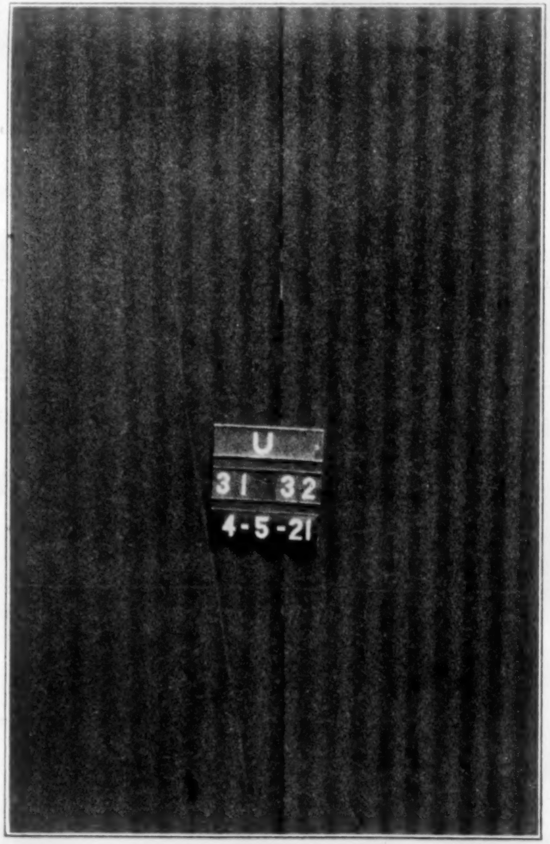

FIG. 52.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 31...	0.013	0.066	0.007	0.039	0.002	0.268	0.010
U 32...	0.014	0.066	0.007	0.034	....	0.249	0.015

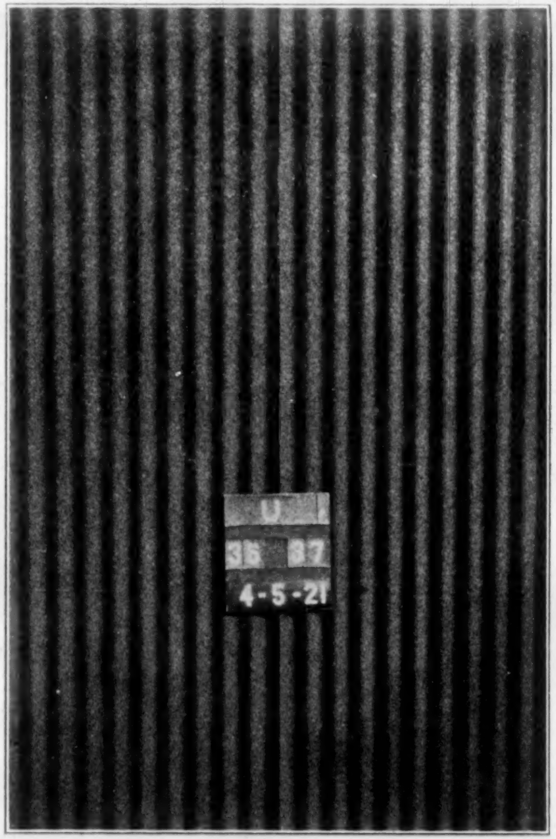

FIG. 53.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 36...	0.02	0.072	0.007	0.048	0.001	0.246	None
U 37...	0.04	0.12	0.004	0.040	Trace	0.28	None

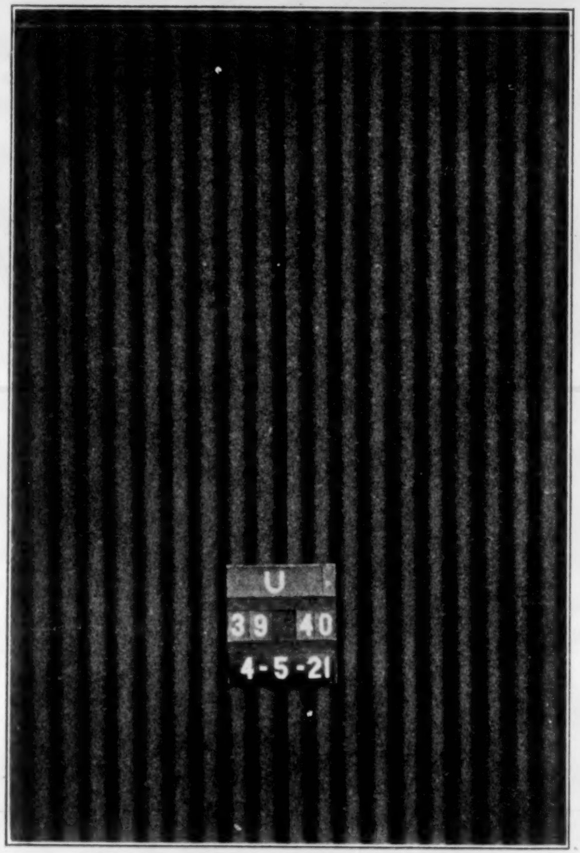

FIG. 54.—PITTSBURGH TESTS.
NO 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
ALLEGHENY STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
U 39 . . .	0.005	0.08	0.006	0.034	Trace	0.27	None
U 40 . . .	0.01	0.07	0.007	0.040	Trace	0.27	None

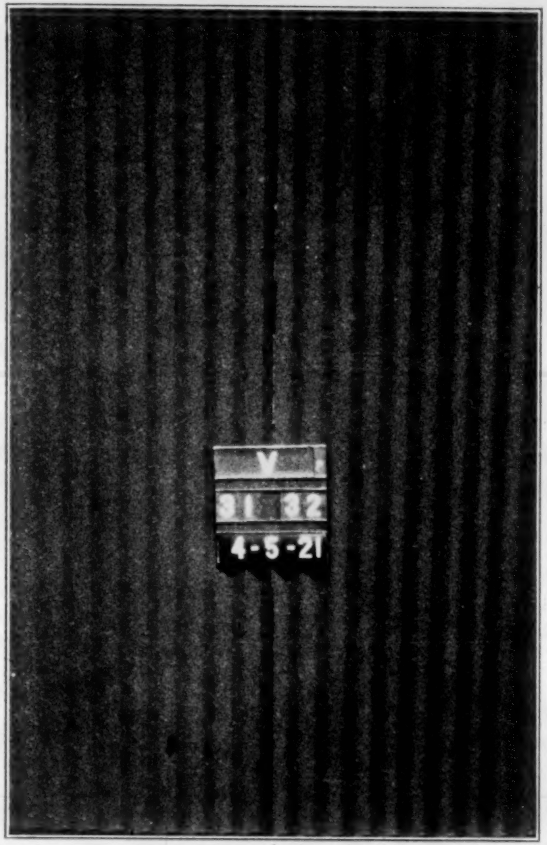

FIG. 55.—PITTSBURGH TESTS.
NO. 22 GAGE COPPER-BEARING PURE IRON—SERIES B.
WHITAKER-GLESSNER CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
V 31 . . .	0.02	0.036	0.006	0.017	. . . .	0.308	None
V 32 . . .	0.02	0.036	0.006	0.024	0.002	0.269	None

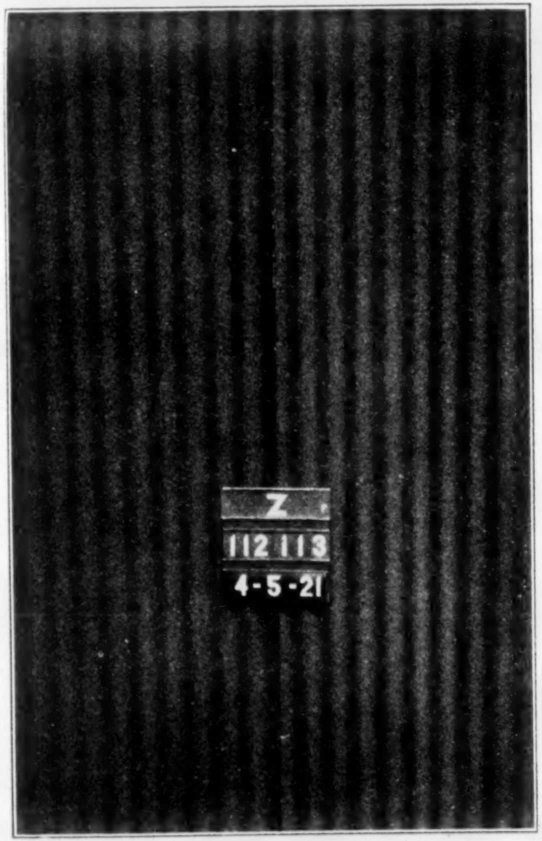

FIG. 56.—PITTSBURGH TESTS.
NO. 22 GAGE BESSEMER STEEL (VARYING COPPER CONTENT)—SERIES B.
YOUNGSTOWN SHEET AND TUBE CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
Z 112 . .	0.07	0.42	0.081	0.048	0.009	0.134	None
Z 113 . .	0.07	0.35	0.089	0.046	0.009	0.128	. . . .

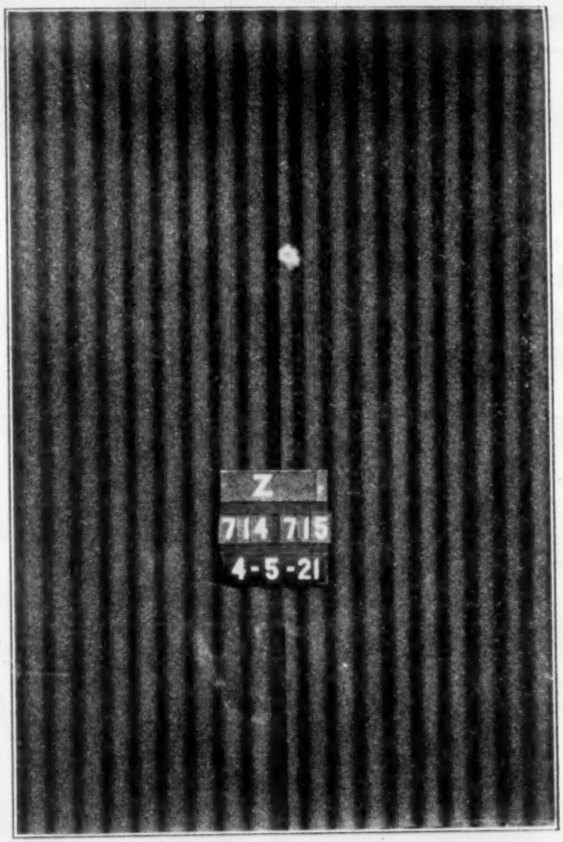

FIG. 57.—PITTSBURGH TESTS.
NO. 22 GAGE OPEN-HEARTH STEEL (VARYING COPPER CONTENT)—SERIES B.
YOUNGSTOWN SHEET AND TUBE CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
Z 714 . .	0.06	0.41	0.037	0.039	Trace	0.520	None
Z 715 . .	0.06	0.41	0.050	0.046	Trace	0.632	None

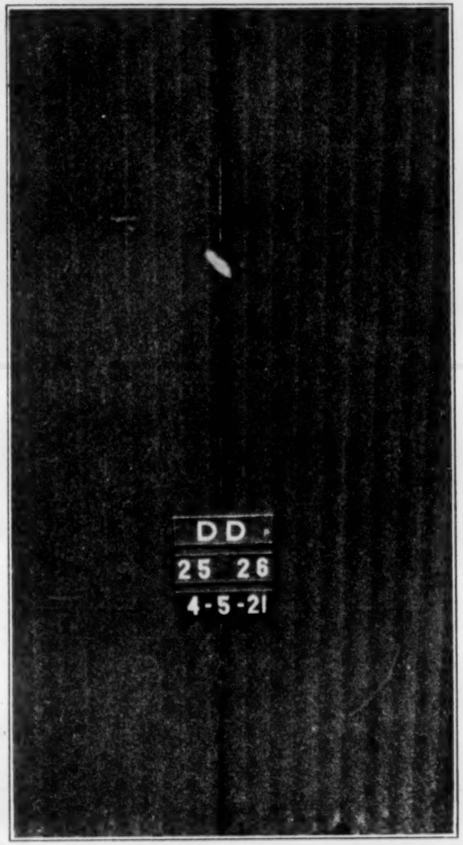

FIG. 58.—PITTSBURGH TESTS.
NO. 16 GAGE LOW-COPPER PURE IRON—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
DD 25.	0.01	0.016	0.003	0.026	0.006	0.025	....
DD 26.	0.01	0.015	0.003	0.029	0.006	0.025	...

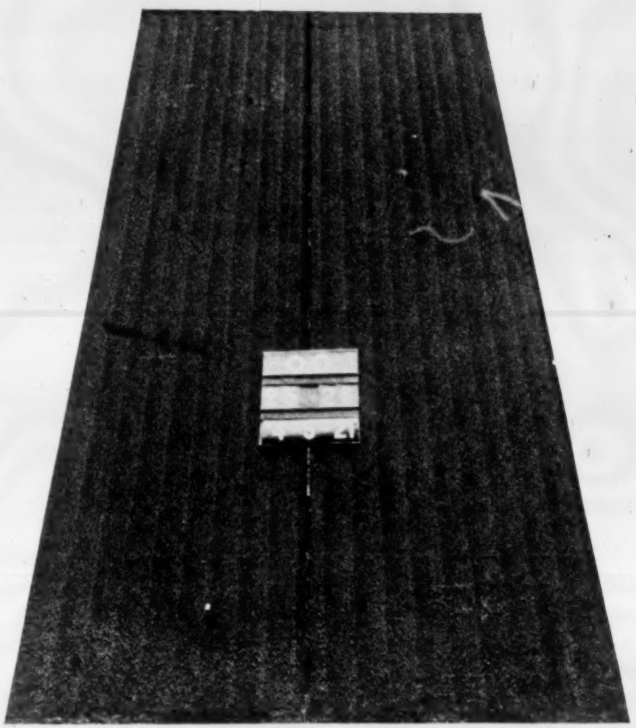

FIG. 59.—PITTSBURGH TESTS.
NO. 16 GAGE LOW-COPPER OPEN-HEARTH STEEL—SERIES A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
OO 25..	0.10	0.38	0.011	0.028	0.009	0.029	....
OO 26..	0.10	0.38	0.006	0.028	0.009	0.030	....

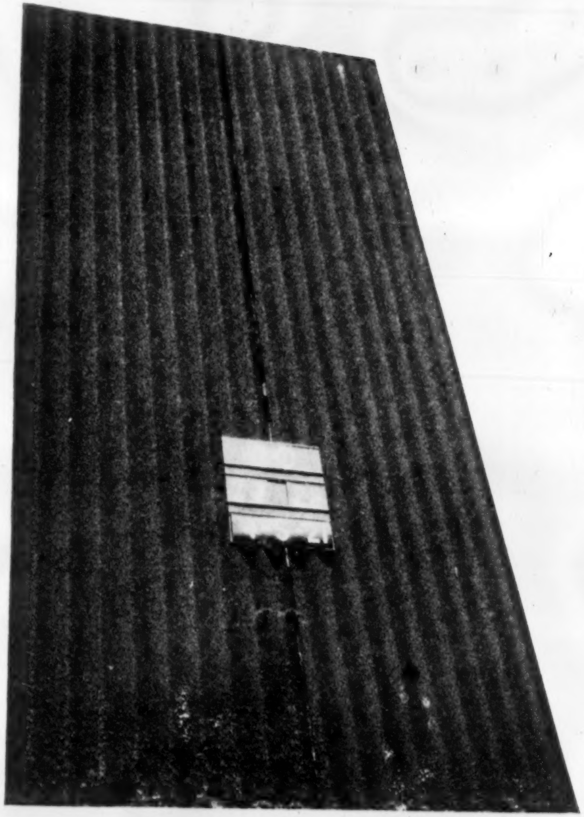

Fig. 60.—Pittsburgh Tests.

No. 16 Gage Low-Copper Open-Hearth Steel—Series A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
OO 27..	0.10	0.38	0.005	0.028	0.009	0.029	....
OO 28..	0.12	0.38	0.010	0.028	0.006	0.020	Trace

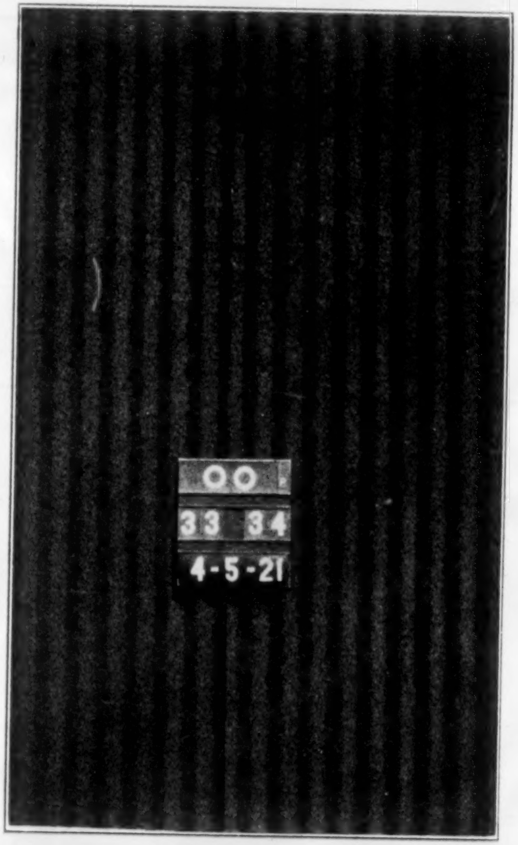

Fig. 61.—Pittsburgh Tests.

No. 16 Gage Low-Copper Open-Hearth Steel—Series A.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
OO 33..	0.11	0.38	0.012	0.027	0.005	0.028	Trace
OO 34..	0.14	0.38	0.012	0.027	0.005	0.036	Trace

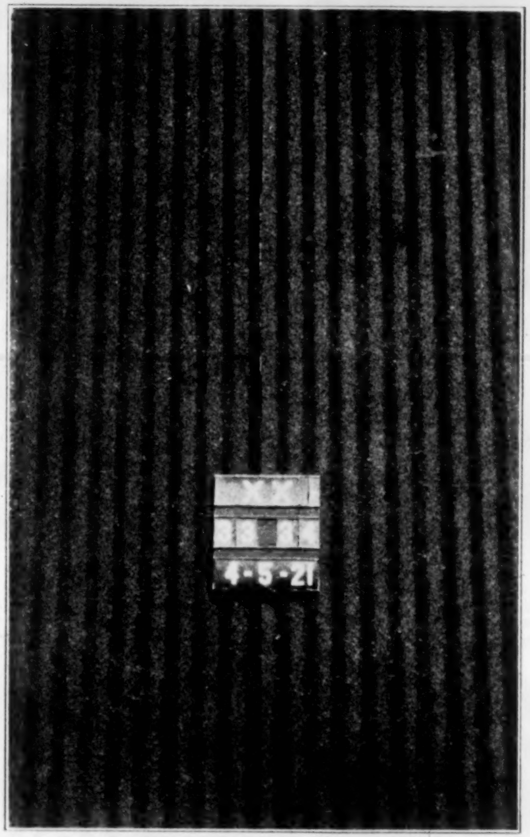

FIG. 62.—PITTSBURGH TESTS
NO. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
INLAND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
XX 33	0.02	0.072	0.006	0.034	....	0.020	None
XX 34	0.02	0.072	0.003	0.028	0.002	0.03	None

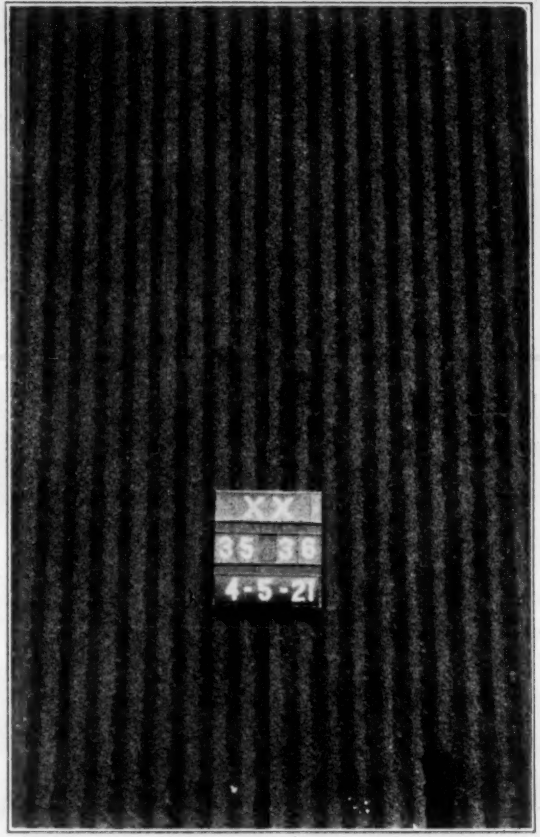

FIG. 63.—PITTSBURGH TESTS.
NO. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
INLAND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
XX 35	0.02	0.07	0.008	0.029	Trace	0.04	None
XX 36	0.02	0.07	0.006	0.032	Trace	0.03	None

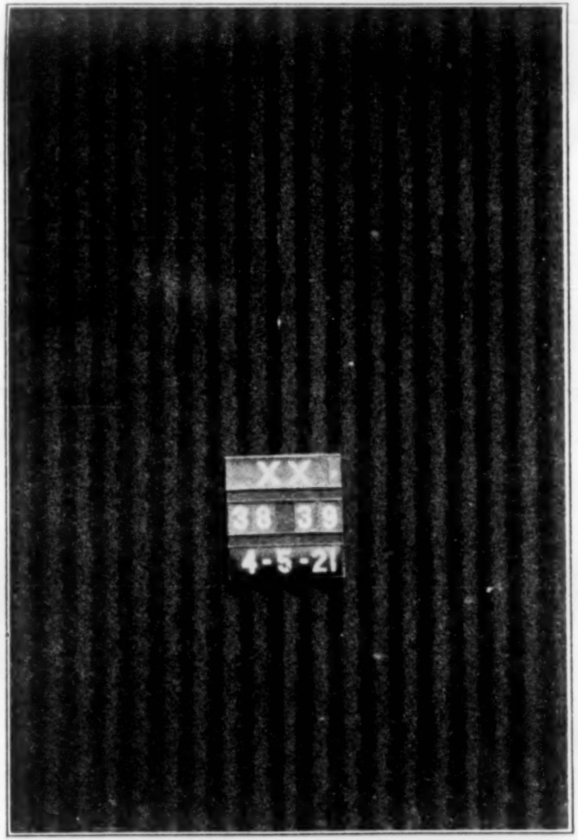

FIG. 64.—PITTSBURGH TESTS.
NO. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
INLAND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
XX 38.	0.25	0.06	0.009	0.035	Trace	0.03	None
XX 39.	0.01	0.07	0.004	0.027	Trace	0.03	None

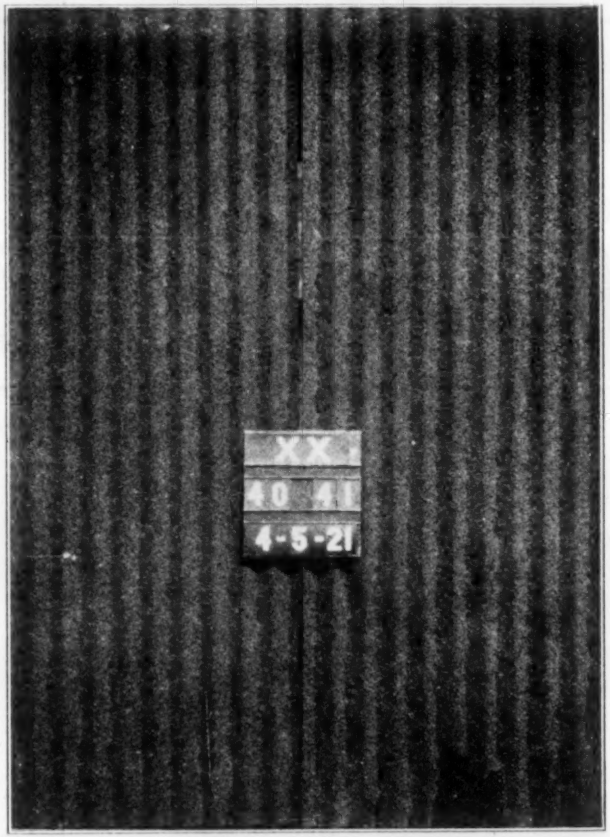

FIG. 65.—PITTSBURGH TESTS.
NO. 16 GAGE LOW-COPPER PURE IRON—SERIES B.
INLAND STEEL CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
XX 40.	0.02	0.06	0.004	0.026	Trace	0.025	None
XX 41.	0.015	0.06	0.006	0.041	Trace	0.025	None

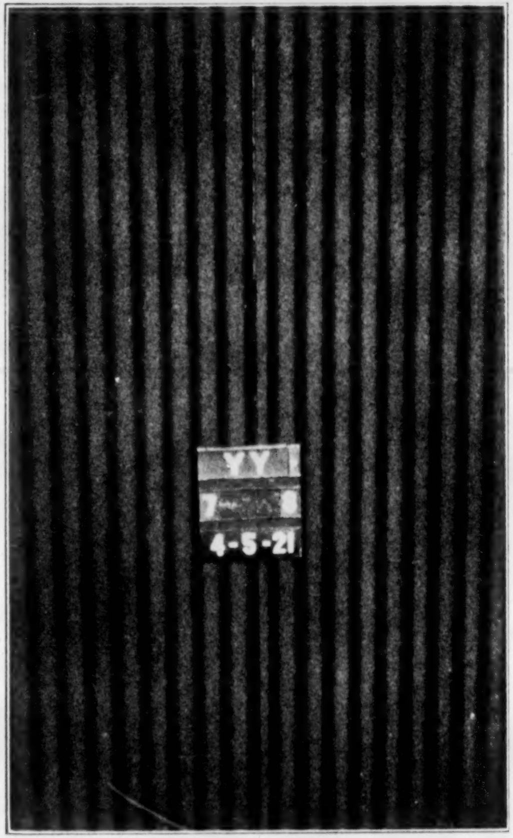

FIG. 66.—PITTSBURGH TESTS.
No. 16 GAGE LOW-COPPER WROUGHT IRON—SERIES B.
YOUNGSTOWN SHEET AND TUBE CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
YY 7...	00.3	0.06	0.111	0.018	0.19	0.24	....
YY 8...	00.3	0.05	0.130	0.018	0.20	0.024	....

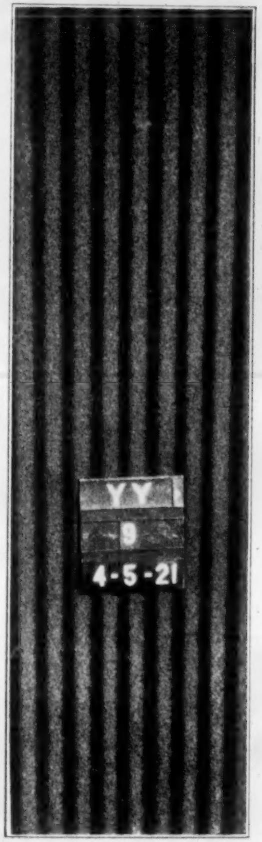

FIG. 67.—PITTSBURGH TESTS.
No. 16 GAGE LOW-COPPER WROUGHT IRON—SERIES B.
YOUNGSTOWN SHEET AND TUBE CO.

Sheet.	C.	Mn.	P.	S.	Si.	Cu.	Ni.
YY 9...	0.03	0.05	0.122	0.018	0.19	0.024	..

REPORT OF SUB-COMMITTEE V ON TOTAL IMMERSION TESTS.

Sub-Committee V on Total Immersion Tests has to report that all the test pieces, both No. 22 gage and No. 16 gage in the test racks in the Pittsburgh district, which were immersed in the water pumped from the Calumet Mine of the H. C. Frick Coke Co. at Calumet, Pa., have failed. This test was under the care of the Bureau of Mines Experiment Station at Pittsburgh, Pa., and under the personal attention of Mr. W. A. Selvig, Assistant Chemist, and had most careful attention and the sub-committee feels under great obligation to them for the interest they have taken in the tests.

The report which Mr. Selvig made to us was most comprehensive and covers the subject very thoroughly and is as follows:

MINE WATER IMMERSION TESTS.

W. A. SELVIG, ASSISTANT CHEMIST, BUREAU OF MINES, PITTSBURGH, PA.

The mine water immersion tests were made at the Calumet Mine of the H. C. Frick Coke Co. at Calumet, Pa. This is a bituminous coal mine, the water from which is considered about the average in acidity in the western Pennsylvania coal region.

Two wooden boxes, one for the No. 16 gage test pieces, and one for the No. 22 gage test pieces were made according to specifications furnished by Sub-Committee V. Each box was provided with six racks, the test pieces being placed in these racks as specified by Sub-Committee V. The two boxes were kept under lock and key, and only opened for the periodical inspections.

The water from the Calumet Mine is pumped by wooden-lined pumps into wooden-lined concrete towers erected over the bore holes. Each tower is divided into two compartments, one of which acts as a standpipe into which the water is pumped from the mine below. When the water in this compartment reaches the top of the division wall, it overflows into the other compartment, from the bottom of which a concrete drain leads to a tower between the bore holes. This tower is similar to those over the bore holes, the water filling one compartment and overflowing into the second, thence through a covered concrete drain to a mine water neutralizing plant.

The two boxes containing the test piece were placed over the concrete drain leading from the tower to the neutralizing plant. Two holes were drilled through the concrete drain and wooden tubes inserted. The mine water was conducted into the inlet end of the wood boxes containing the test pieces by means of rubber hose, as shown in the photograph. The water was delivered into each box at a rate of 6 gal. per minute. This rate of flow was checked at each inspection period and was very constant throughout the test.

The two boxes were carefully levelled so that the overflow was of even depth over the entire width of the outlet. The test pieces were completely submerged in the water during the test.

The test pieces which had been all carefully weighed were placed in the mine water on August 6, 1920. Inspections were made at one week intervals from

August 6, 1920, to October 22, 1920, and at two week intervals from October 22, 1920, to January 20, 1921, the pieces, with the exception of test piece YY-6, having all failed at the latter date. The No. 22 gage test pieces all failed during the period when inspections were made at the one week intervals.

At each inspection, the flow of water into each box was measured, the temperature of the water in the boxes taken, and samples collected for determination of acidity. At the inspection periods the racks containing the test pieces were all removed from the boxes and each individual piece examined. The test pieces were considered failed and were removed when an indentation of $\frac{1}{4}$ in. in depth appeared on the edges of the plates or perforations were found through the plates. The failed plates were placed in manilla envelopes and kept until the completion of the test when all the plates were cleaned free from rust with a 15 per cent ammonium citrate solution, weighed and photographed.

Samples of the mine water were taken at each inspection from the water as it was delivered from the rubber hose into the inlet end of the boxes. Glass bottles provided with glass stoppers were used as containers for the water, the bottles being completely filled with the water. The water was titrated the day following the collection, for acidity due to free mineral acids and acidity due to free mineral acids plus acidity of sulfates of iron and aluminum. The date of inspection, acidity due to free mineral acids, acidity due to free mineral acids plus acidity of sulfates of iron and aluminum, and the water temperature in the boxes are as follows:

ACIDITY AND TEMPERATURE OF CALUMET MINE WATER DURING TEST.

Date.	Acidity, Parts per Million in Terms of Calcium Carbonate.		Water Temperature, Deg. Cent.[a]
	Acidity Due to Free Sulfuric Acid.	Acidity Due to Free Sulfuric Acid Plus Sulfates of Iron and Aluminum.	
Aug. 6, 1920	740	(*b*)	16.0
Aug. 13, 1920	750	(*b*)	16.7
Aug. 20, 1920	715	1675	17.0
Aug. 27, 1920	770	1755	17.0
Sept. 3, 1920	785	1780	16.5
Sept. 10, 1920	770	1665	17.2
Sept. 17, 1920	700	2105	17.8
Sept. 24, 1920	650	2115	16.7
Oct. 1, 1920	600	1895	15.1
Oct. 8, 1920	840	1845	15.5
Oct. 15, 1920	680	1715	15.6
Oct. 22, 1920	675	1640	16.5
Oct. 29, 1920	685	1625	15.7
Nov. 12, 1920	750	1600	15.0
Nov. 26, 1920	620	1605	13.0
Dec. 9, 1920	670	1580	(*c*)
Dec. 23, 1920	780	1590	14.5
Jan. 6, 1921	635	1525	14.5
Jan. 20, 1921	700	1560	12.8

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[a] Water temperatures taken in middle of boxes.

[b] Not determined.

[c] Not taken, due to breaking of thermometer.

In determining the acidity of the mine water the methods as given in "Standard Methods of Water Analysis," American Public Health Association, 1920, p. 41, were used. Due to the large amount of iron in the water it was found necessary to dilute the water 1 to 10 before making titrations; otherwise satisfactory end points could not be obtained.

In mine water containing large amounts of sulfates of iron and aluminum as occur in the Calumet water, titration methods for the determination of free mineral acids are not satisfactory due to the hydrolysis of ferric sulfate during the titration with the liberation of free acid, thus giving too high results. The acidity due to free mineral acids as given in the table is no doubt too high due to partial hydrolysis of ferric sulfate; however, the amount of free mineral acids plus sulfates of iron and aluminum can be determined accurately and is possibly of greater importance than the amount of free acid present. The sulfates of iron and aluminum in solution are a latent source of free acidity as these salts will hydrolize readily and liberate free sulfuric acid as the free acid of the water is neutralized. Tests were made at various times to determine the relative amounts of ferrous sulfate, ($FeSO_4$) and ferric sulfate ($Fe_2(So_4)_3$) and were as follows:

FERROUS AND FERRIC SULFATE IN MINE WATER,
PARTS PER MILLION.

DATE.	FERROUS SULFATE ($FeSO_4$)	FERRIC SULFATE $Fe_2(SO_4)_3$	TOTAL IRON SULFATES. (FERROUS SULFATE PLUS FERRIC SULFATE.
October 1	331	849	1180
October 15	247	900	1147
October 29	316	869	1185
November 12	286	1051	1337

It was not possible to determine dissolved oxygen in the water by the standard chemical methods due to the interference of the sulfates of iron. The large amount of ferrous sulfate in the water would indicate that very little dissolved oxygen occurred.

It was noted that the plates in the racks nearest the inlet end of the boxes corroded more rapidly than those in the racks near the outlet end. One plate of each iron or steel was represented in each rack so this progressive corrosion from the inlet to the outlet of the box was due to the difference of the action of the water in various parts of the box. The average life of the plates in each rack before failure is given below. Rack No. 1 was placed near the inlet end, rack No. VI near the outlet end, the other racks being placed in numerical order from I to VI.

RACK NO.	BOX I, NO. 22 GAGE PLATES, AVERAGE LIFE IN DAYS.	BOX II, NO. 16 GAGE PLATES, AVERAGE LIFE IN DAYS.
I	37.3	100.2
II	42.6	110.1
III	44.6	118.7
IV	49.3	125.6
V	55.4	133.1
VI	56.0	127.1

TABLE I.—REPORT ON SUBMERGED TESTS. TESTS EXPOSED AUGUST 6, 1920, IN THE WATER RUNNING FROM THE CALUMET MINE—PITTSBURGH DISTRICT.

NO. 16 GAGE SHEETS.

Group.	Designation.	Series.	Description.	Average Analysis.						Number of sheets in Test.
				Carbon.	Manganese.	Phosphorus.	Sulfur.	Silicon.	Copper.	
AA	Bessemer Steel	A	Non-Copper-Bearing	0.03	0.40	0.083	0.040	0.003	0.016	6
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.08	0.45	0.103	0.039	....	0.015	6
ZZ2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	Copper-Bearing	0.083	0.34	0.098	0.038	....	0.284	6
II	Copper-Bearing Bessemer Steel	A	" "	0.062	0.38	0.089	0.068	0.008	0.244	6
ZZ3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.065	0.355	0.083	0.033	....	0.528	6
ZZ1	Copper-Bearing Bessemer Steel Youngstown Sheet and Tube Co.	B	" "	0.09	0.40	0.098	0.040	0.004	0.156	6
OO	Low-Copper Open-Hearth Steel	A	Non-Copper-Bearing	0.112	0.367	0.007	0.027	0.005	0.035	6
BB	Open-Hearth Steel	A	" " "	0.08	0.426	0.019	0.036	0.06	0.076	6
ZZ4	Low-Copper Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.021	0.388	0.038	0.033	0.006	0.033	6
MM	Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" " "	0.102	0.393	0.013	0.030	0.004	0.052	6
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	Copper-Bearing	0.082	0.315	0.011	0.018	0.011	0.242	6
HH	Copper-Bearing Basic Open-Hearth Steel	A	" "	0.057	0.362	0.012	0.026	0.003	0.238	6
ZZ5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.066	0.380	0.063	0.067	0.009	0.233	6
ZZ7	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.390	0.049	0.044	....	0.328	6
ZZ6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	"	0.090	0.341	0.035	0.073	0.002	0.629	6
DD	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.012	0.022	0.003	0.026	0.005	0.030	6
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.016	0.017	0.006	0.019	....	0.023	6
CC	Copper-Bearing Pure Iron	A	" " "	0.015	0.022	0.004	0.032	0.002	0.063	6
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.017	0.054	0.008	0.030	0.002	0.026	6
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	Copper-Bearing	0.013	0.065	0.008	0.027	0.007	0.246	6
CCC	Copper-Bearing Pure Iron	A	" "	0.024	0.030	0.005	0.029	0.006	0.236	6
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.010	0.041	0.008	0.019	....	0.304	6
KK	Copper-Bearing Acid Open-Hearth Steel	A	" "	0.107	0.435	0.087	0.042	....	0.241	6
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.03	0.053	0.124	0.018	0.216	0.021	6
EE	Puddled Iron	A	Copper-Bearing	0.025	0.023	0.122	0.018	0.115	0.322	6

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[1] Inspections were made on October 1, 8, and 15, but no failures were reported at these inspections.

TABLE I.—REPORT ON SUBMERGED TESTS. TESTS EXPOSED AUGUST 6, 1920, IN THE WATER RUNNING FROM THE CALUMET MINE—PITTSBURGH DISTRICT.

No. 16 GAGE SHEETS.

Group.	Failures on Date of Inspections.[1]											
	Sept. 24, 1920. 49 Days.	Oct. 22, 1920. 77 Days.	Oct. 29, 1920. 84 Days.	Nov. 12, 1920. 98 Days.	Nov. 26, 1920. 112 Days.	Dec. 9, 1920. 125 Days.	Dec. 23, 1920. 139 Days.	Jan. 6, 1921. 153 Days.	Jan. 20, 1921. 167 Days.	Average Number of Days.	Average Number of Days.	Average Number of Days.
AA		19					22 28 25 31	34		131	135.08	127.86
ZZ					4	5	5	5 7 7		139.16		
ZZ2					204 205 205 206		206 206			121	124.25	
II					26 38 28	31	33 37			123.16		
ZZ3					308 308	308 309 309		309		125.33		
ZZ1					107	102 107 102	107 107			127.5		
OO				14 15	13 28 17 30					107.33	114.21	113.55
BB	18				21 42	24 39	27			110.33		
ZZ4				419	419	419 420 420 420				118.33		
MM				16	18 20	22	27 29			120.83		
TT		13		15 18 16 21	24					96.83	113.03	
HH		20		22	26 32	28 34				108.16		
ZZ5					502 506 502	505 506 505				118.5		
ZZ7					711 712 712 712	713	713			118.66		
ZZ6			610		610	611 612	611	611		123.		
DD				24 26	28 40 35	32				109.5	124.25	113.43
SS				19	25	21 22	27 28			123.		
CC					12 14	18	16 22	20		130.		
XX					29	30 40	26 28		26	134.5		
UU	13	18		11 16	21 24					91.	99.	
CCC		18	17 21	22	25		24			99.		
VV				34 39 38 35		37 42				107.		
KK			26	20	23 34	30 32				109.33	109.33	109.33
YY							6	6 7	6 7 6	157.66		142.66
EE				11 13		15	20	16 17		127.66		

TABLE I. *(Continued)*.—REPORT ON SUBMERGED TESTS. TESTS EXPOSED AUGUST 6, 1920, IN THE WATER RUNNING FROM THE CALUMET MINE—PITTSBURGH DISTRICT.

NO. 22 GAGE SHEETS.

Group.	Designation.	Series.	Description.	Average Analysis.						
				Carbon.	Manganese.	Phosphorus.	Sulfur	Silicon.	Copper.	Number of Sheets in Test.
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.053	0.415	0.118	0.045	0.006	0.010	6
A	Bessemer Steel	A	" " "	0.043	0.388	0.086	0.039	0.012	0.012	6
Z1	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.067	0.395	0.086	0.045	0.009	**0.136**	6
I	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.03	0.372	0.093	0.069	0.009	0.261	6
Z3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.053	0.370	0.114	0.048	....	0.532	6
Z2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.385	0.092	0.036	0.007	0.263	6
O	Low-Copper Open-Hearth Steel	A	Non-Copper-Bearing	0.13	0.528	0.008	0.028	0.218	0.023	6
Z4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.320	0.061	0.041	....	0.019	6
Z5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	Copper-Bearing	0.066	0.356	0.044	0.051	....	0.189	6
B	Open-Hearth Steel	A	" "	0.073	0.252	0.011	0.056	0.003	0.163	6
H	Copper-Bearing Basic Open-Hearth Steel	A	" "	0.057	0.387	0.008	0.027	0.004	0.242	6
Z7	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.065	0.405	0.052	0.053	....	0.611	6
M	Open-Hearth Steel, Alan Wood Iron and Steel Co.	B	" "	0.09	0.43	0.016	0.039	0.014	0.182	6
Z6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.07	0.37	0.051	0.054	0.003	0.264	6
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.077	0.307	0.008	0.020	0.009	0.227	6
X	Low-Copper Pure Iron, Inland Steel Co.	B	Non-Copper-Bearing	0.02	0.043	0.006	0.028	0.006	0.025	6
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.016	0.023	0.007	0.019	0.004	0.019	6
D	Low-Copper Pure Iron	A	" " "	0.011	0.033	0.003	0.018	0.002	0.013	6
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	Copper-Bearing	0.016	0.075	0.008	0.035	0.004	0.268	6
C	Copper-Bearing Pure Iron	A	" "	0.024	0.029	0.004	0.032	0.002	0.174	6
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	"	0.015	0.045	0.007	0.018	....	0.308	6
K	Copper-Bearing Acid Open-Hearth Steel	A	" "	0.097	0.471	0.092	0.044	0.002	0.241	6
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.050	0.141	0.020	0.206	0.018	6
E	Puddled Iron	A	Copper-Bearing	0.027	0.039	0.112	0.021	0.147	0.297	6

TABLE I. (*Continued*).—REPORT ON SUBMERGED TESTS. TESTS EXPOSED AUGUST 6, 1920, IN THE WATER RUNNING FROM THE CALUMET MINE—PITTSBURGH DISTRICT.

NO. 22 GAGE SHEETS.

Group.	Failures on Date of Inspections.										
	Sept. 3, 1920. 28 Days.	Sept. 10, 1920. 35 Days.	Sept. 17, 1920. 42 Days.	Sept. 24, 1920. 49 Days.	Oct. 1, 1920. 56 Days.	Oct. 8, 1920. 63 Days.	Oct. 15, 1920. 70 Days.	Oct. 22, 1920. 77 Days.	Average Number of Days.	Average Number of Days.	Average Number of Days.
Z		5	5 5		6	6	6		51.33	55 6	51 7
A			15 20 22			28 35 37			52.5		
Z1			109		109 109		111	111 111	63		
I	23	21 27 30 33	18						35	47.83	
Z3			306 306	306	308	308 308			52.5		
Z2			208		208 208 209 209		209		56		
O	15	16 17 29	28 30						36.16	40.25	44 85
Z4		418	418 419	419 420 420					44.33		
Z5	504	504 506	504 506	506					38.5	46.16	
B		17 19 21 23	27		25				39.66		
H	26 29	20 23			32 35				39.66		
Z7		709 712	709		709 712 712				46.66		
M		16	18 22	20		26	24		50.16		
Z6		603 603			604 604 604	604			50.16		
T		25			26 27 28		29	33	58.33		
X		14 18 25	22	19		27			43.16	47.44	46 27
S			15 25	19 21 23	17				47.83		
D			20 23	25	28 31	29			51.33		
U	22 24	16 18 20			27				36.16	45.11	
C		16 18 20	14 42	24					39.66		
V		14		15		19	21 23 25		59.5		
K		18 24		21	27		30 33		52.5	52.5	52 5
Y	4		4 5		5 6 6				46.66	46.66	48.41
E			18 20	14	16 22 24				50.16	50.1	

This progressive corrosion may have resulted from a higher concentration of free acid and oxygen at the inlet of the box or to a difference in the flow of water around the plates at the various racks. Unfortunately the determination of free acid in this mine water was not of sufficient accuracy to detect slight variations of acidity, due to the presence of large amounts of iron and aluminum sulfates. Colored solutions were introduced at the inlet of the boxes and the currents traced. It was found that the racks near the inlet of the box were subjected to stronger currents than the racks near the outlet, this no doubt played an important role in this difference of rate of corrosion from the inlet to the outlet ends of the boxes.

Table I was prepared for the No. 22 gage and for the No. 16 gage test pieces. In both cases, grouping the various grades of metal and subdividing these grades with reference to the presence of copper, into Copper-Bearing and Non-Copper-Bearing. The tables give the average analyses of the test pieces, the number of test pieces in each lot and the date of the failure of each test piece and the average life of each lot. The average of the group is first sub-divided into Copper and Non-Copper-Bearing and then the average taken for the entire group.

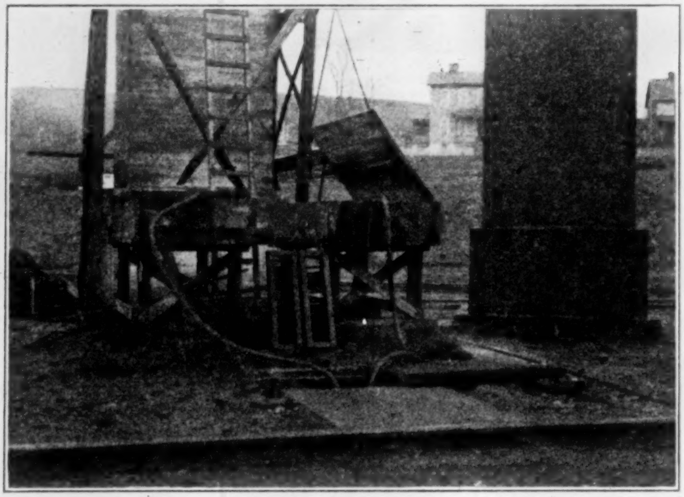


FIG. 1.—Arrangement of Boxes for Mine Water Immersion Tests.

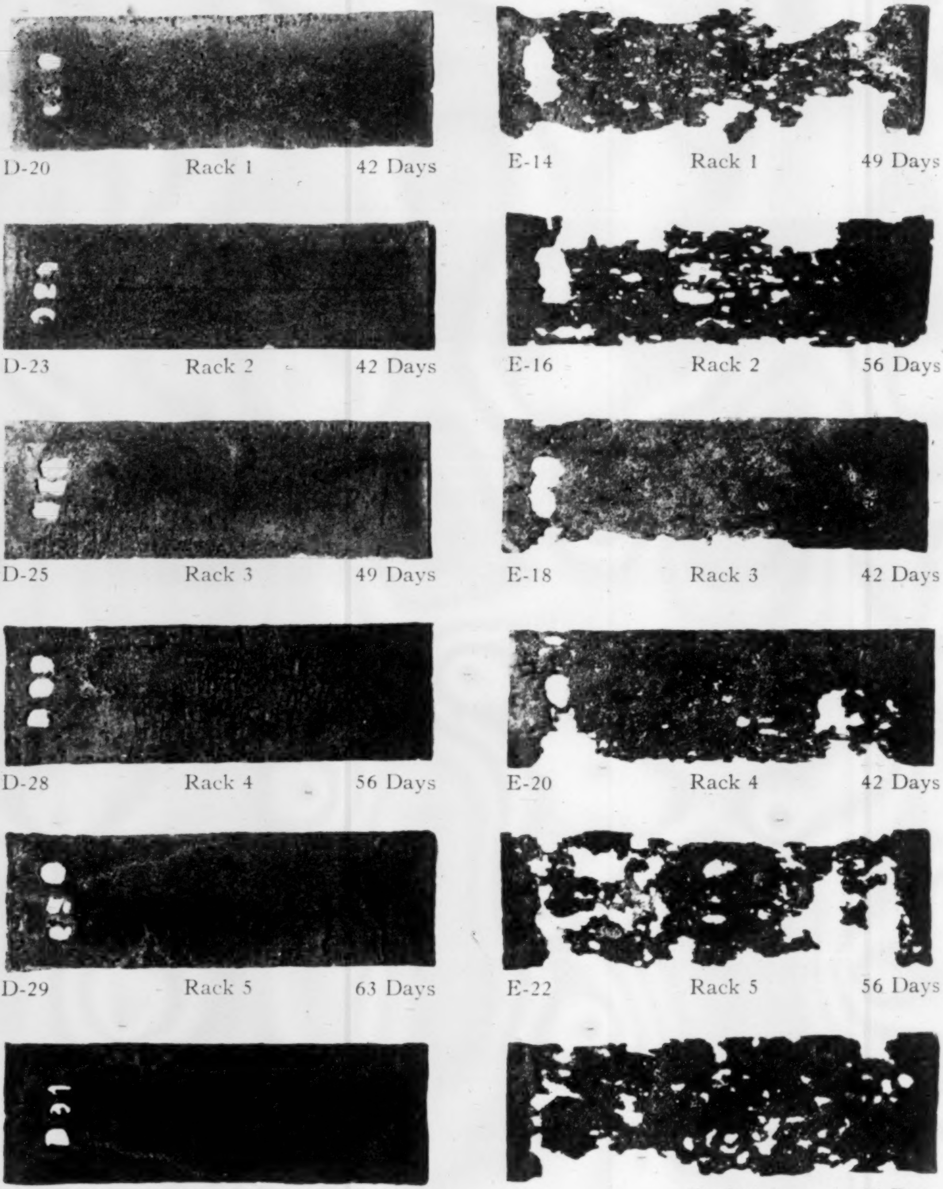
It must be remembered that these test pieces are cut from the same sheets which are exposed in the atmospheric tests and by comparison with the groups which have failed in the atmosphere it will be noted the results are quite different. In the immersion tests under the conditions which prevail at the Calumet Mine, the presence of copper would indicate little influence on the life of the specimen and if any difference, the presence of copper would seem to give a slightly shorter life, also the order of failure of the various groups is decidedly changed but it would be safer not to draw definite conclusions until we have the finished results of the various atmospheric and immersion tests.

The Bureau of Mines took photographs of all the test pieces after failure, which show the character of the failures, these are arranged with the six test pieces of each lot on one print and are reproduced on the following pages. A failure consisted of an indentation on the edge of at least $\frac{1}{4}$ in. or a hole on the surface of the sheet and in no case was it considered a failure when a hole developed where the test piece was stamped. In many cases the holes were so small that they do not show on the photographs, but when the test piece was held before the light they plainly showed the hole.

At the tests under way at the Naval Experiment Station at Annapolis, and at the Bureau of Standards in Washington, there have been no failures as yet, and at both Stations they are under careful attention.

Respectfully submitted on behalf of the sub-committee,

WILLIAM A. COOPER,
Chairman.



D-20 Rack 1 42 Days

D-23 Rack 2 42 Days

D-25 Rack 3 49 Days

D-28 Rack 4 56 Days

D-29 Rack 5 63 Days

D-31 Rack 6 56 Days

E-14 Rack 1 49 Days

E-16 Rack 2 56 Days

E-18 Rack 3 42 Days

E-20 Rack 4 42 Days

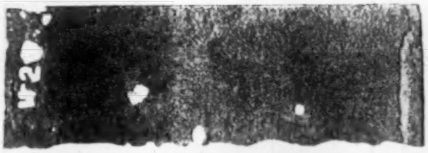
E-22 Rack 5 56 Days

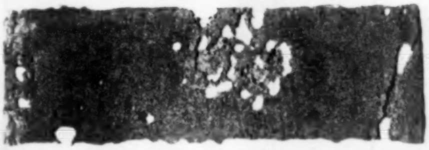
E-24 Rack 6 56 Days

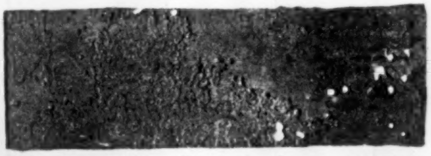
(*a*) Low-Copper Pure Iron
Average, 51.33 Days

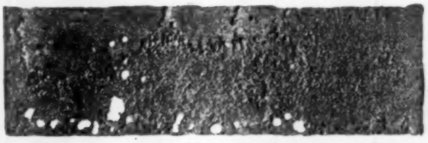
(*b*) Copper-Bearing Puddle Iron
Average, 50.1 Days

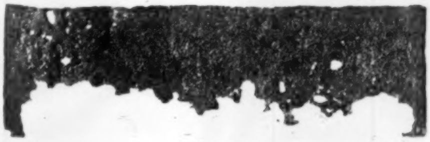
FIG. 2.—Calumet Mine Water Test. No. 22 Gage.

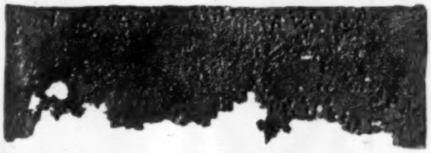

H-20 Rack 1 35 Days


H-23 Rack 2 35 Days

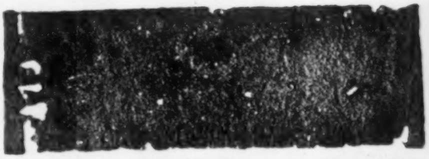

H-26 Rack 3 28 Days

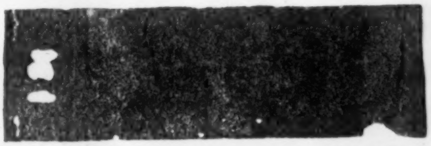

H-29 Rack 4 28 Days

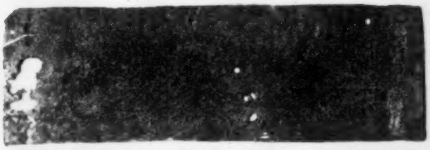

H-32 Rack 5 56 Days

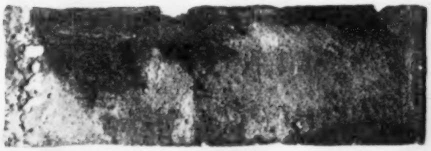

H-35 Rack 6 56 Days

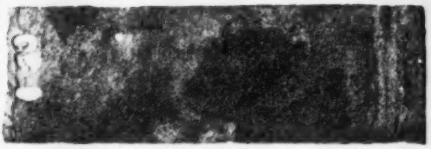
(*a*) Copper-Bearing Basic Open-Hearth Steel
Average, 39.66 Days

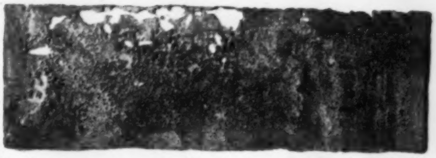

I-18 Rack 1 42 Days


I-21 Rack 2 35 Days


I-23 Rack 3 28 Days

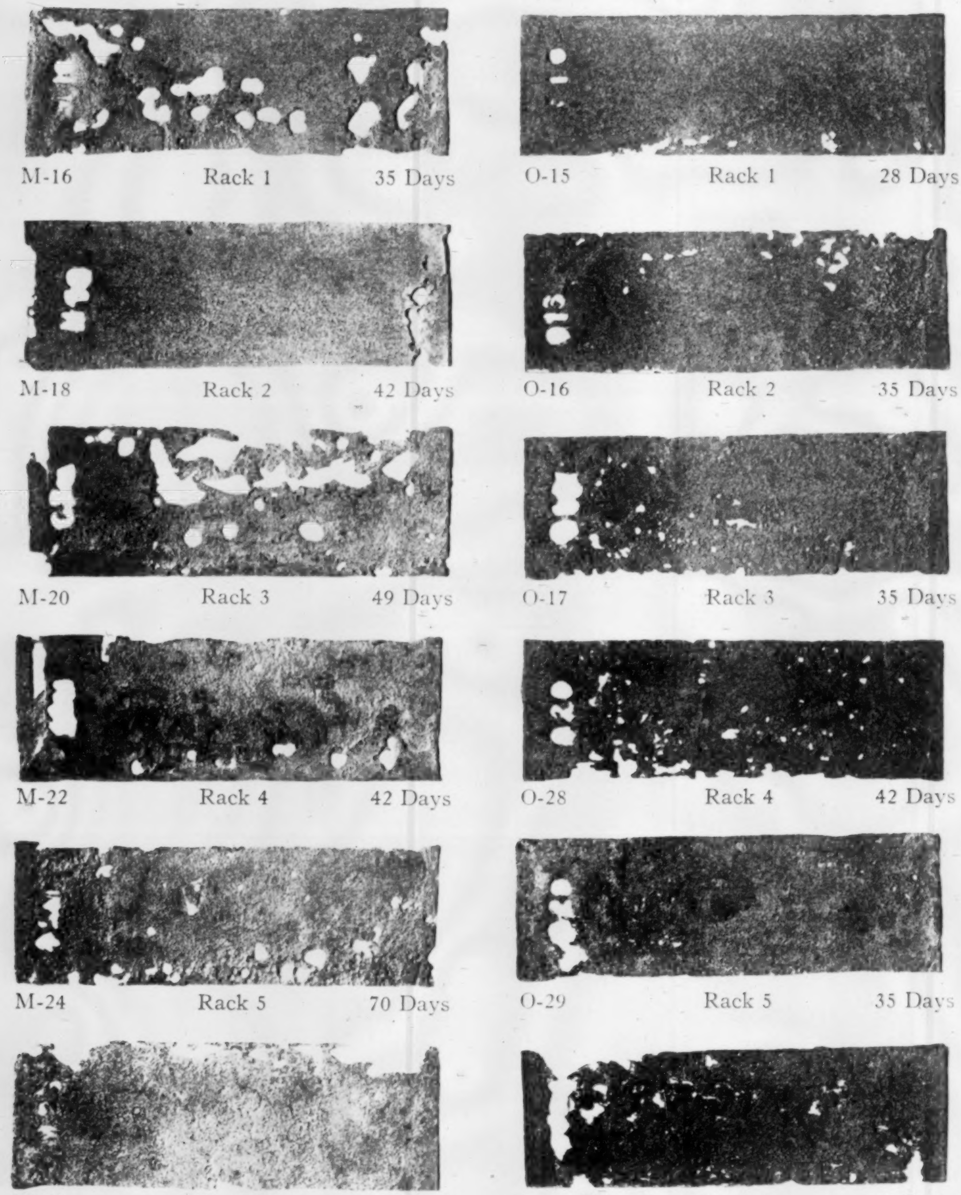

I-27 Rack 4 35 Days


I-30 Rack 5 35 Days


I-33 Rack 6 35 Days

(*b*) Copper-Bearing Bessemer Steel
Average, 35 Days

FIG. 3.—Calumet Mine Water Test. No. 22 Gage.



M-16 Rack 1 35 Days

M-18 Rack 2 42 Days

M-20 Rack 3 49 Days

M-22 Rack 4 42 Days

M-24 Rack 5 70 Days

M-26 Rack 6 63 Days.

O-15 Rack 1 28 Days

O-16 Rack 2 35 Days

O-17 Rack 3 35 Days

O-28 Rack 4 42 Days

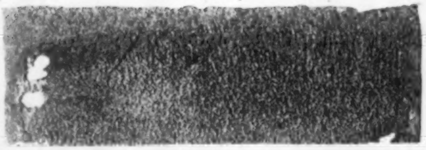
O-29 Rack 5 35 Days

O-30 Rack 6 42 Days

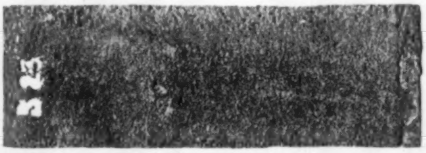
(*a*) Copper-Bearing Basic Open-Hearth Steel
Alan Wood Iron and Steel Co.
Average, 50.1 Days

(*b*) Low-Copper Basic Open-Hearth Steel
Inland Steel Co.
Average, 36.16 Days

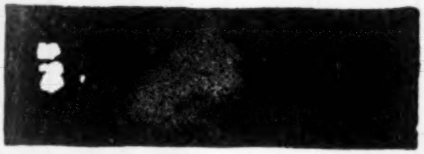
FIG. 4.—Calumet Mine Water Test. No. 22 Gage.



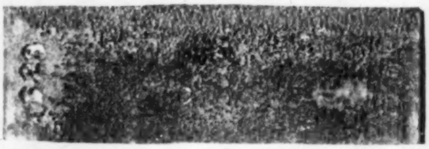
S-15 Rack 1 42 Days



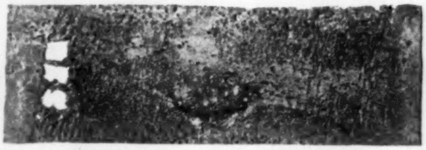
S-17 Rack 2 56 Days



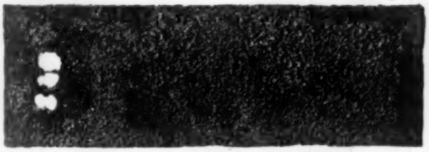
S-19 Rack 3 49 Days



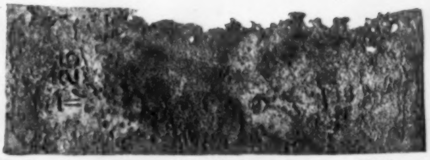
S-21 Rack 4 49 Days



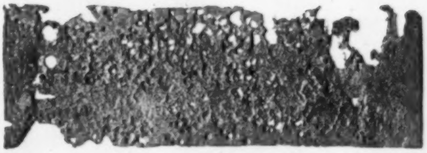
S-23 Rack 5 49 Days



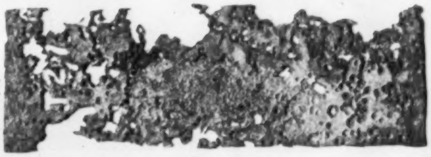
S-25 Rack 6 42 Days



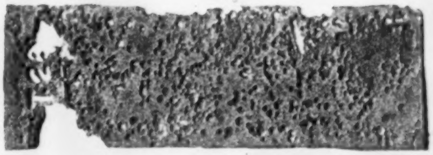
T-25 Rack 1 35 Days



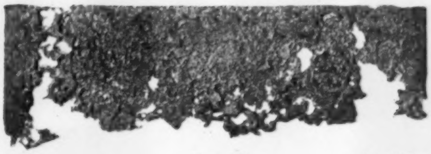
T-26 Rack 2 56 Days



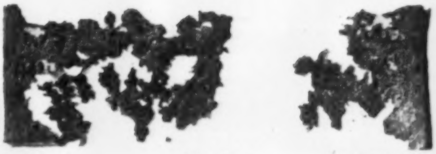
T-27 Rack 3 56 Days



T-28 Rack 4 56 Days



T-29 Rack 5 70 Days

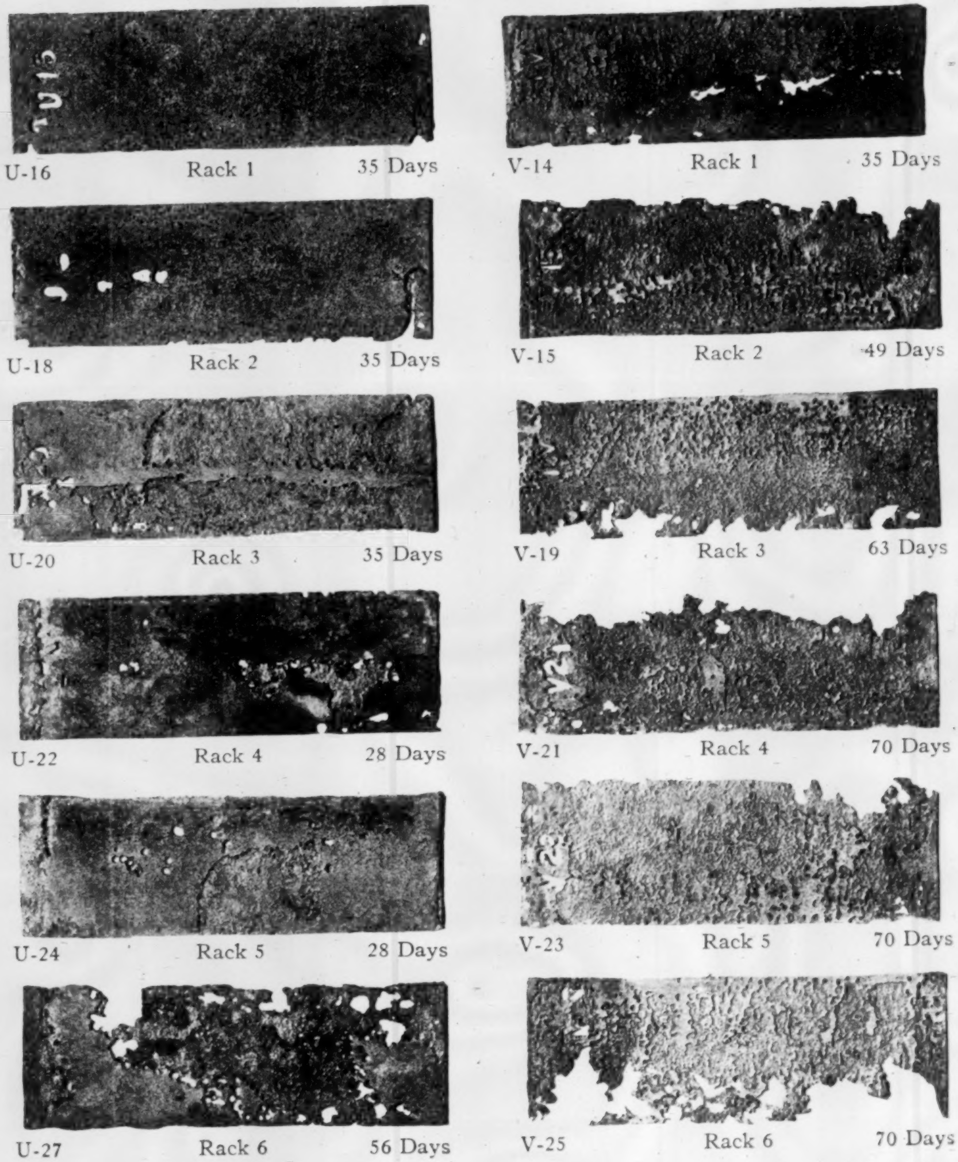


T-33 Rack 6 77 Days

(*a*) Low-Copper Pure Iron
American Rolling Mill Co.
Average, 47.8 Days

(*b*) Copper-Bearing Basic Open-Hearth Steel
Newport Rolling Mill Co.
Average, 58.33 Days

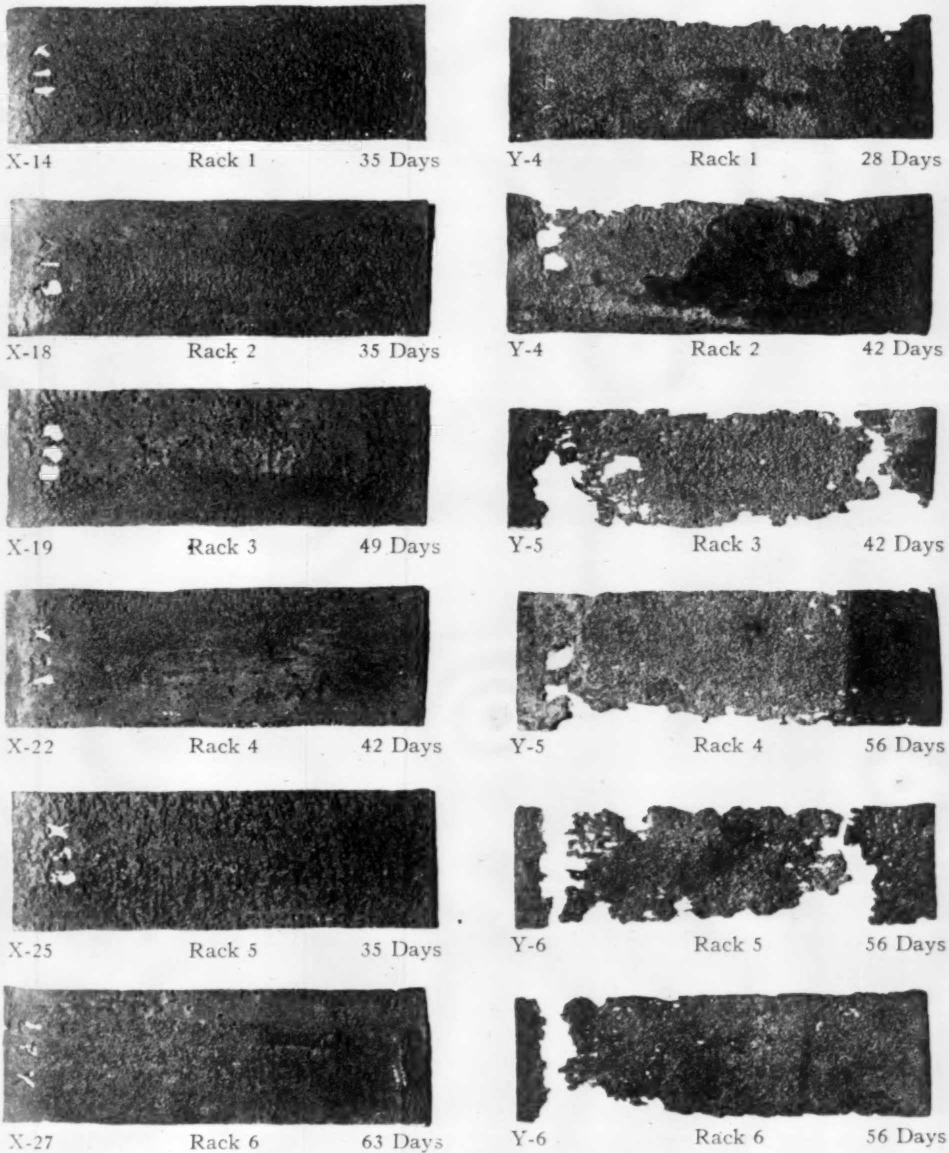
FIG. 5.—Calumet Mine Water Test. No. 22 Gage.


U-16 Rack 1 35 Days
V-14 Rack 1 35 Days
U-18 Rack 2 35 Days
V-15 Rack 2 49 Days
U-20 Rack 3 35 Days
V-19 Rack 3 63 Days
U-22 Rack 4 28 Days
V-21 Rack 4 70 Days
U-24 Rack 5 28 Days
V-23 Rack 5 70 Days
U-27 Rack 6 56 Days
V-25 Rack 6 70 Days

(*a*) Copper-Bearing Pure Iron
Allegheny Steel Co.
Average, 36.16 Days

(*b*) Copper-Bearing Pure Iron
Whitaker-Glessner Co.
Average, 59.5 Days

FIG. 6.—Calumet Mine Water Test. No. 22 Gage.



X-14 Rack 1 35 Days

X-18 Rack 2 35 Days

X-19 Rack 3 49 Days

X-22 Rack 4 42 Days

X-25 Rack 5 35 Days

X-27 Rack 6 63 Days

Y-4 Rack 1 28 Days

Y-4 Rack 2 42 Days

Y-5 Rack 3 42 Days

Y-5 Rack 4 56 Days

Y-6 Rack 5 56 Days

Y-6 Rack 6 56 Days

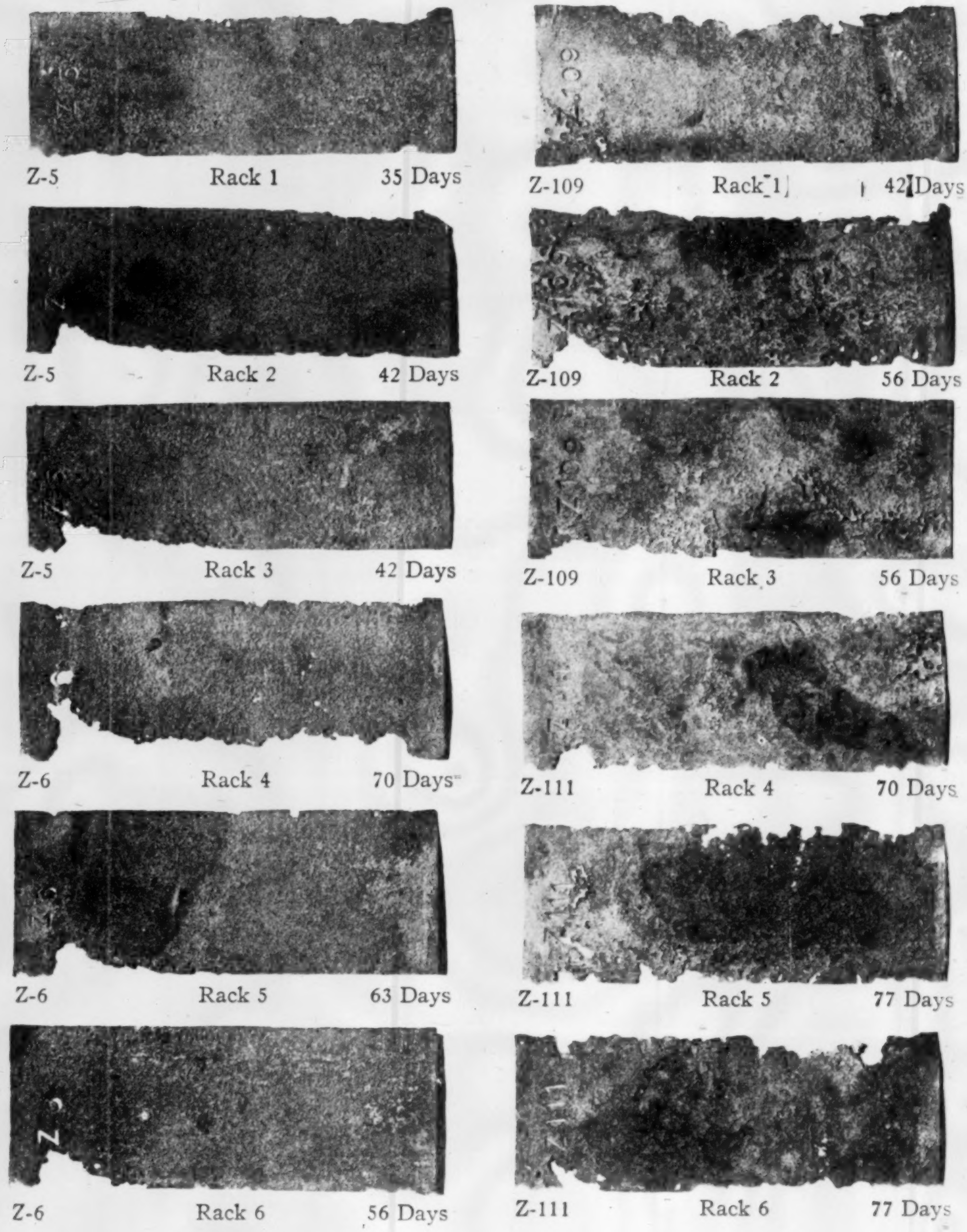
(*a*) Low-Copper Pure Iron
Inland Steel Co.

Average, 43.16 Days

(*b*) Low-Copper Puddle Iron
Youngstown Sheet and Tube Co.

Average, 46.66 Days

FIG. 7.—Calumet Mine Water Test. No. 22 Gage.


Z-5 Rack 1 35 Days
Z-109 Rack 1 42 Days
Z-5 Rack 2 42 Days
Z-109 Rack 2 56 Days
Z-5 Rack 3 42 Days
Z-109 Rack 3 56 Days
Z-6 Rack 4 70 Days
Z-111 Rack 4 70 Days
Z-6 Rack 5 63 Days
Z-111 Rack 5 77 Days
Z-6 Rack 6 56 Days
Z-111 Rack 6 77 Days

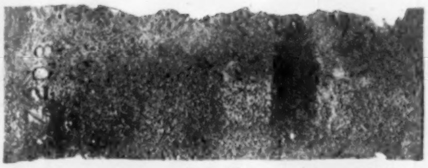
(*a*) Low-Copper Bessemer Steel Youngstown Sheet and Tube Co.

Average, 51.33 Days

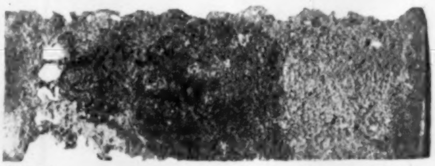
(*b*) Copper-Bearing Bessemer Steel. Average Copper, 0.136

Average, 63 Days

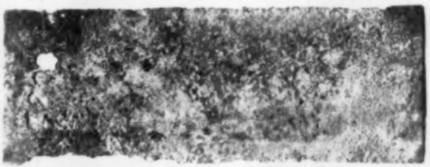
FIG. 8.—Calumet Mine Water Test. No. 22 Gage.



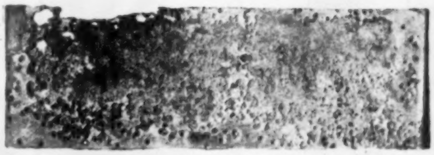
Z-208 Rack 1 42 Days



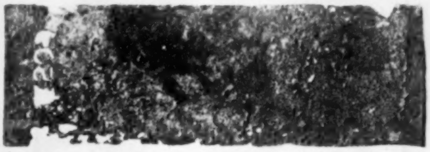
Z-208 Rack 2 56 Days



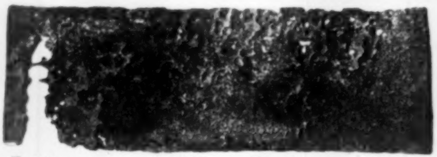
Z-208 Rack 3 56 Days



Z-209 Rack 4 56 Days

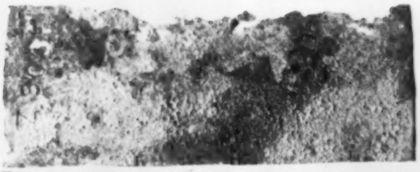


Z-209 Rack 5 70 Days

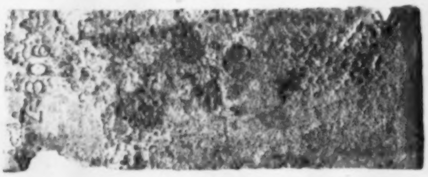


Z-209 Rack 6 56 Days

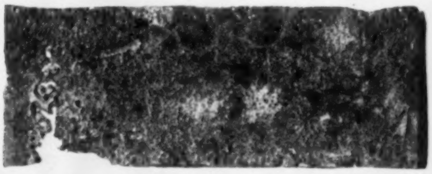
(*a*) Copper-Bearing Bessemer Steel. Average Copper, 0.263
Average, 56 Days



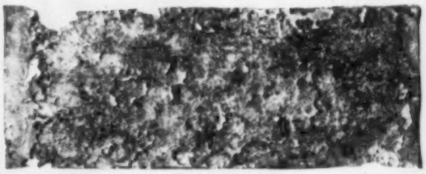
Z-306 Rack 1 42 Days



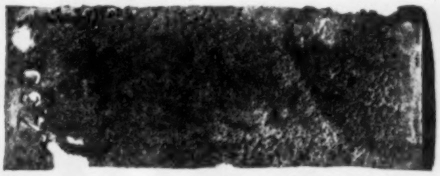
Z-306 Rack 2 42 Days



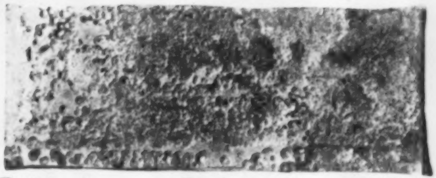
Z-306 Rack 3 49 Days



Z-308 Rack 4 63 Days



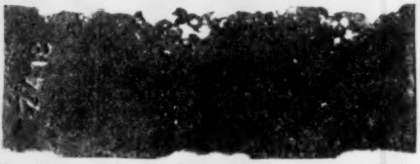
Z-308 Rack 5 63 Days

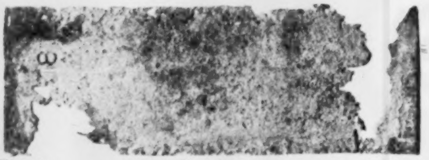


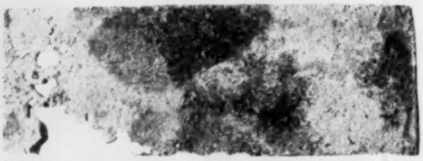
Z-308 Rack 6 56 Days

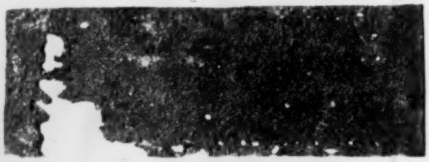
(*b*) Copper-Bearing Bessemer Steel. Average Copper, 0.532
Average, 52.5 Days

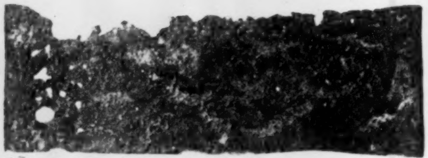
FIG. 9.—Calumet Mine Water Test. No. 22 Gage.

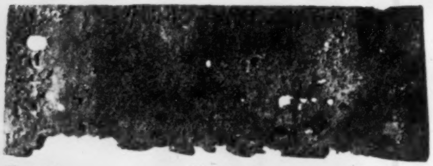

Z-418 Rack 1 35 Days


Z-418 Rack 2 42 Days

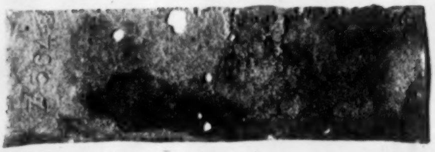

Z-419 Rack 3 42 Days


Z-419 Rack 4 49 Days

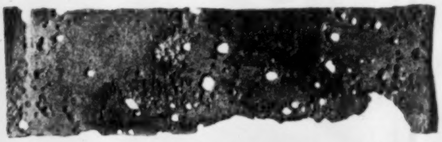

Z-420 Rack 5 49 Days

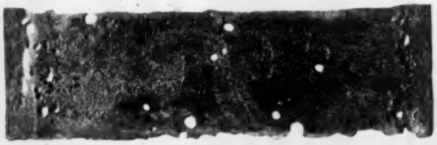

Z-420 Rack 6 49 Days

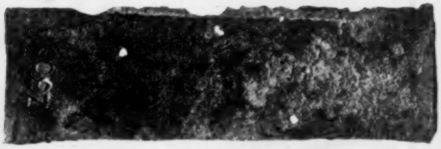
(*a*) Low-Copper Basic Open-Hearth Steel
Average Copper, 0.019
Youngstown Sheet and Tube Co.
Average, 44.33 Days

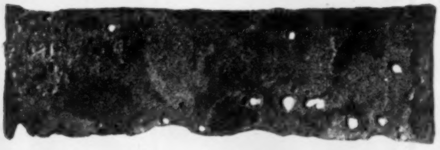

Z-504 Rack 1 28 Days

Z-504 Rack 2 35 Days


Z-504 Rack 3 42 Days

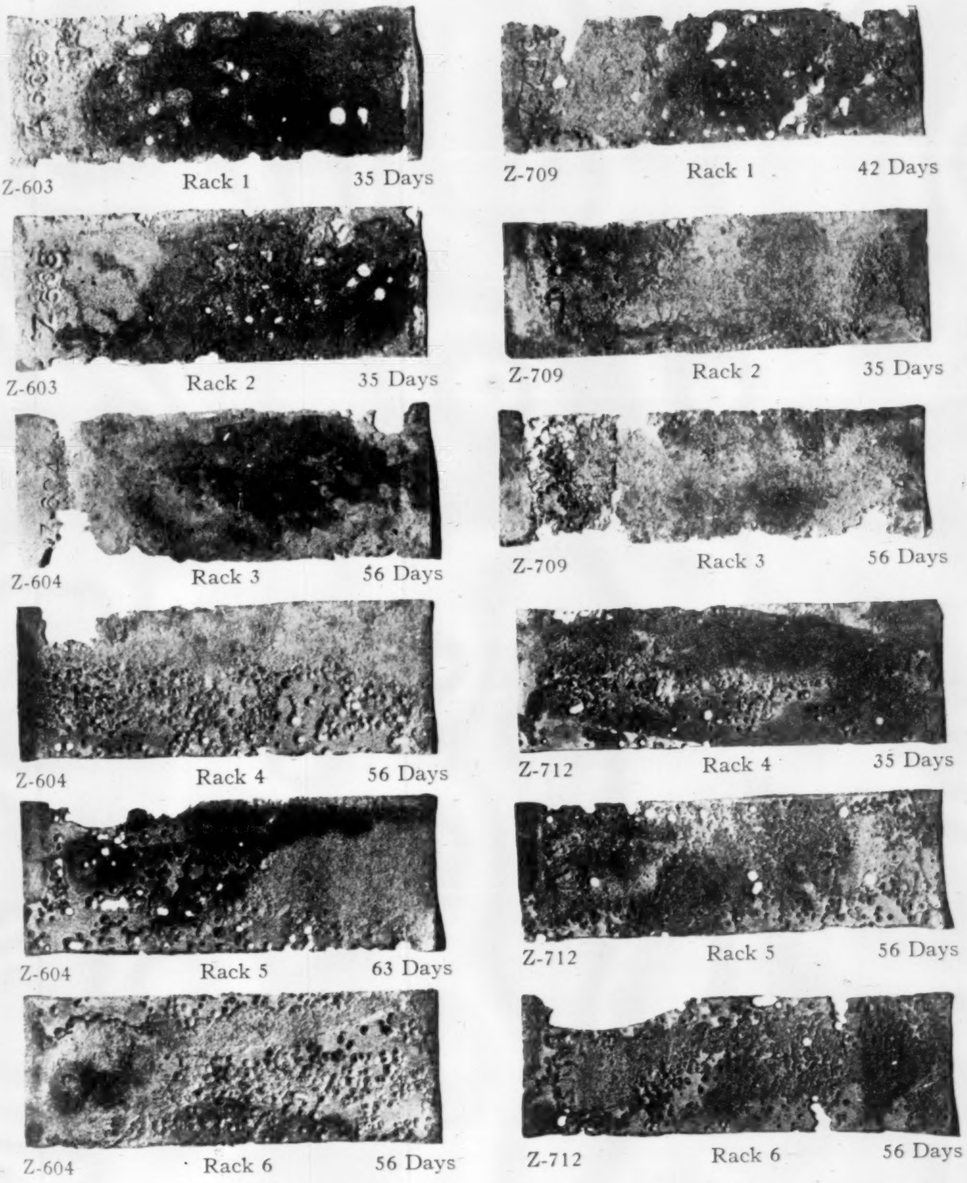

Z-506 Rack 4 49 Days


Z-506 Rack 5 35 Days


Z-506 Rack 6 42 Days

(*b*) Copper-Bearing Basic Open-Hearth Steel
Average Copper, 0.189
Average, 38.5 Days

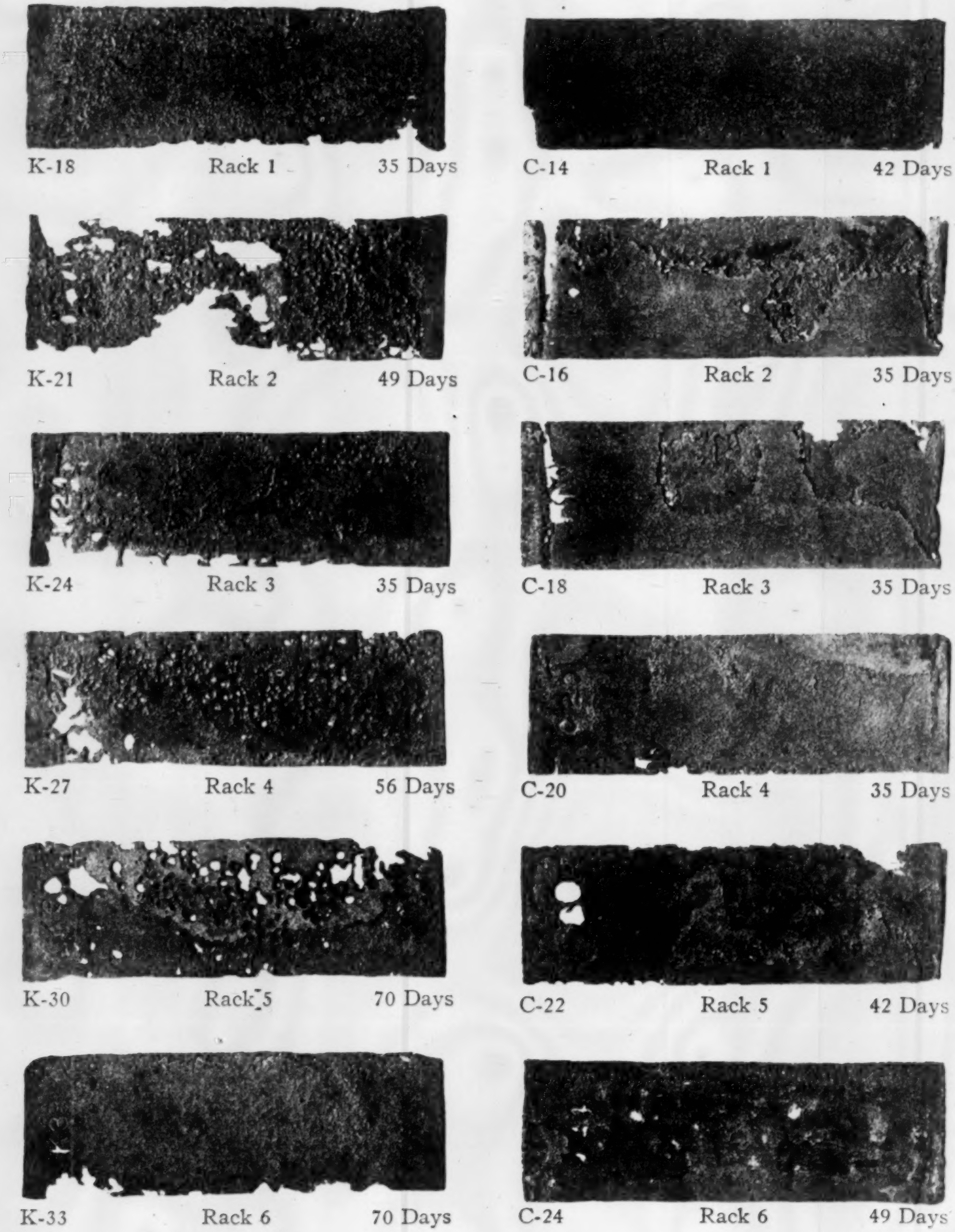
FIG. 10.—Calumet Mine Water Test. No. 22 Gage.


Z-603 Rack 1 35 Days
Z-709 Rack 1 42 Days
Z-603 Rack 2 35 Days
Z-709 Rack 2 35 Days
Z-604 Rack 3 56 Days
Z-709 Rack 3 56 Days
Z-604 Rack 4 56 Days
Z-712 Rack 4 35 Days
Z-604 Rack 5 63 Days
Z-712 Rack 5 56 Days
Z-604 Rack 6 56 Days
Z-712 Rack 6 56 Days

(*a*) Copper-Bearing Basic Open-Hearth Steel
Average Copper, 0.264.
Average, 50.16 Days

(*b*) Copper-Bearing Basic Open-Hearth Steel
Average Copper, 0.611.
Average, 46.66 Days

FIG. 11.—Calumet Mine Water Test. No. 22 Gage.



K-18 Rack 1 35 Days

K-21 Rack 2 49 Days

K-24 Rack 3 35 Days

K-27 Rack 4 56 Days

K-30 Rack 5 70 Days

K-33 Rack 6 70 Days

(*a*) Copper-Bearing Acid Open-Hearth Steel
Average, 52.5 Days

C-14 Rack 1 42 Days

C-16 Rack 2 35 Days

C-18 Rack 3 35 Days

C-20 Rack 4 35 Days

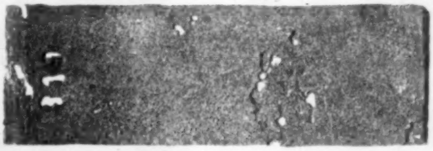
C-22 Rack 5 42 Days

C-24 Rack 6 49 Days

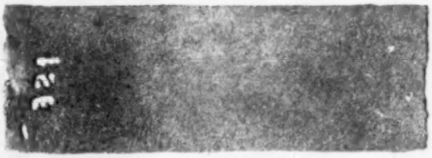
(*b*) Copper-Bearing Pure Iron
Average, 39.66 Days

FIG. 12.—Calumet Mine Water Test. No. 22 Gage.

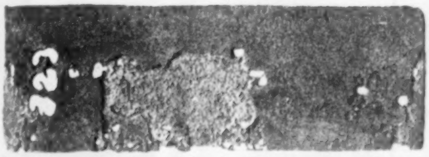
B-17 Rack 1 35 Days]



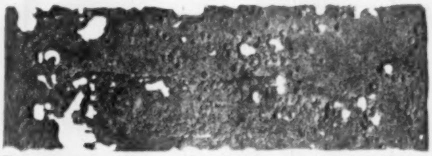
B-19 Rack 2 35 Days



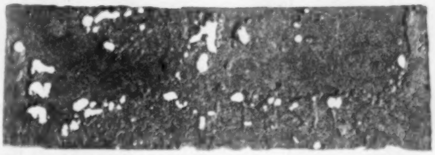
B-21 Rack 3 35 Days



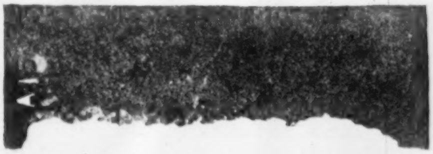
B-23 Rack 4 35 Days



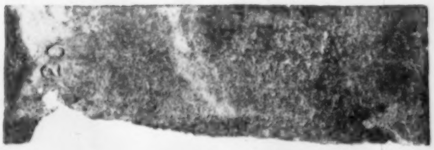
B-25 Rack 5 56 Days



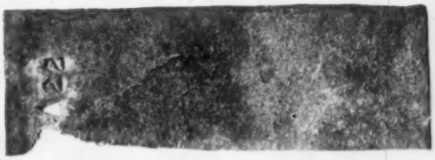
B-27 Rack 6 42 Days



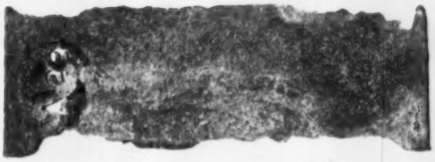
A-15 Rack 1 42 Days



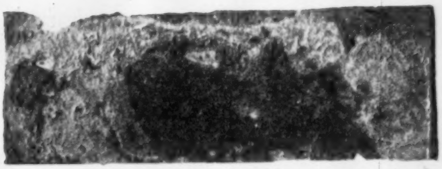
A-20 Rack 2 42 Days



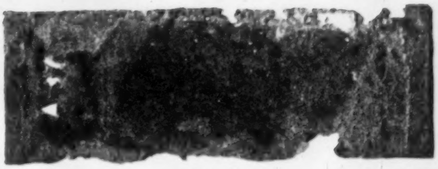
A-22 Rack 3 42 Days



A-28 Rack 4 63 Days



A-35 Rack 5 63 Days

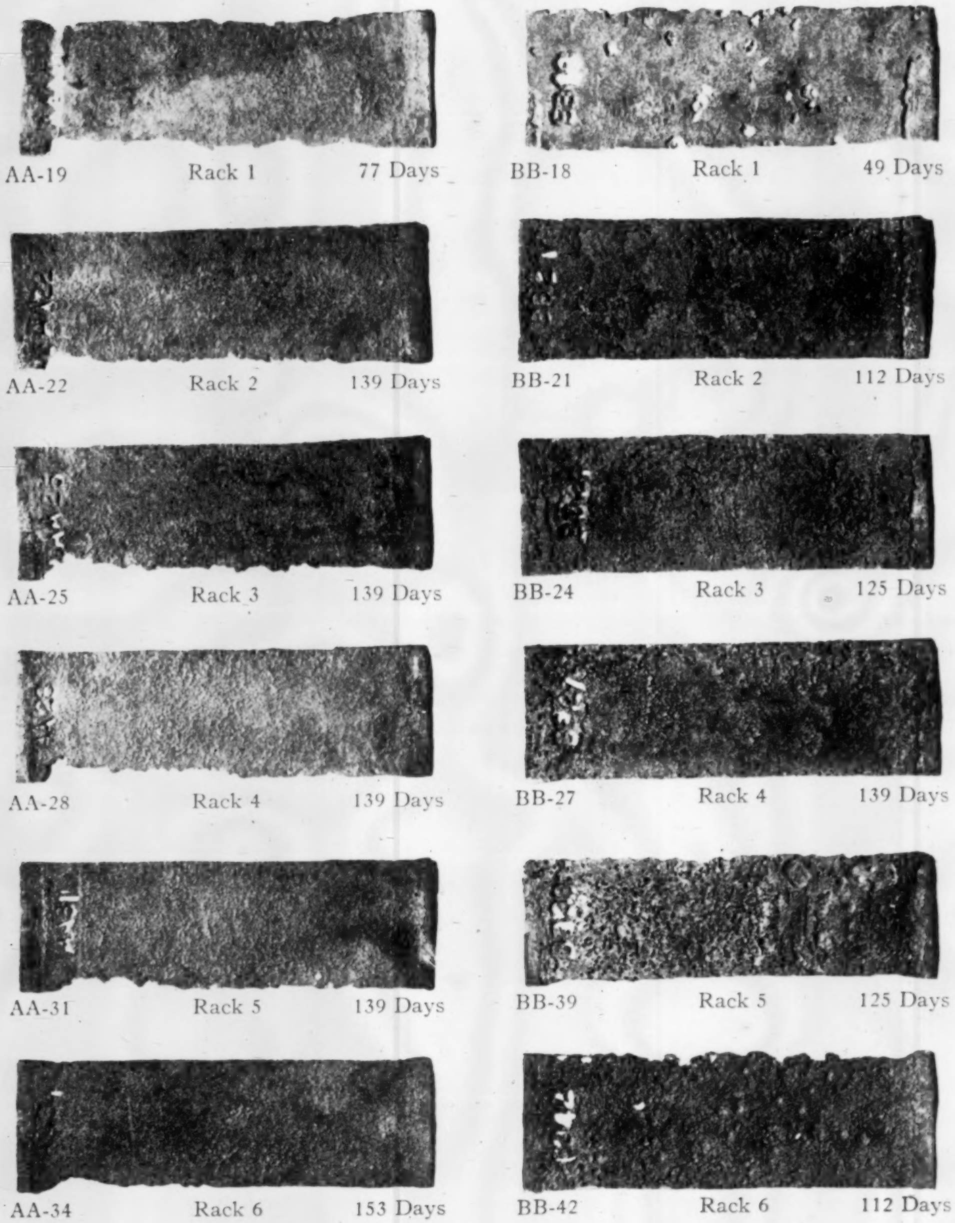


A-37 Rack 6 63 Days

(*a*) Copper-Bearing Basic Open-Hearth Steel
Average, 39.66 Days

(*b*) Low-Copper Bessemer Steel
Average, 52.5 Days

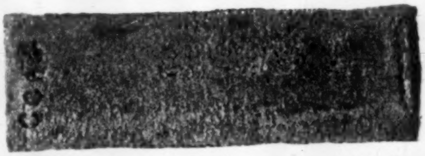
FIG. 13.—Calumet Mine Water Test. No. 22 Gage.


AA-19 Rack 1 77 Days
BB-18 Rack 1 49 Days
AA-22 Rack 2 139 Days
BB-21 Rack 2 112 Days
AA-25 Rack 3 139 Days
BB-24 Rack 3 125 Days
AA-28 Rack 4 139 Days
BB-27 Rack 4 139 Days
AA-31 Rack 5 139 Days
BB-39 Rack 5 125 Days
AA-34 Rack 6 153 Days
BB-42 Rack 6 112 Days

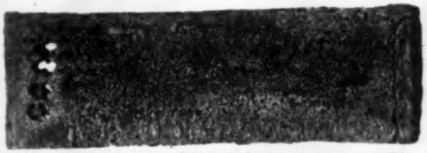
(*a*) Low-Copper Bessemer Steel
Average, 131 Days

(*b*) Low-Copper Basic Open-Hearth Steel
Average, 110.33 Days

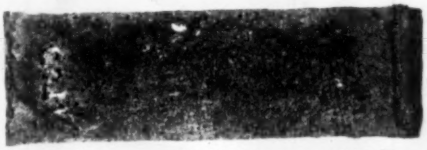
FIG. 14.—Calumet Mine Water Test. No. 16 Gage.



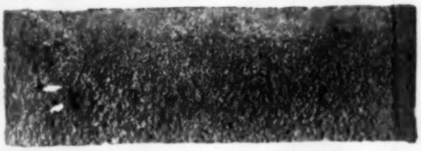
CC-12 Rack 1 112 Days



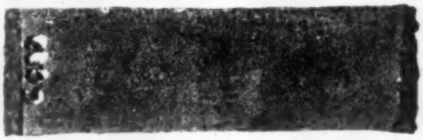
CC-14 Rack 2 112 Days



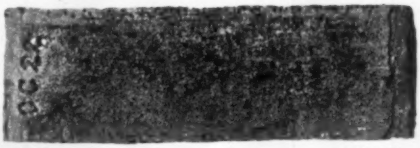
CC-16 Rack 3 139 Days



CC-18 Rack 4 125 Days

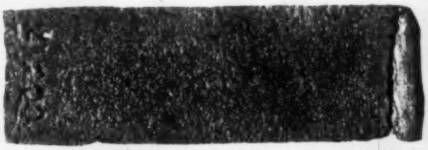


CC-20 Rack 5 153 Days

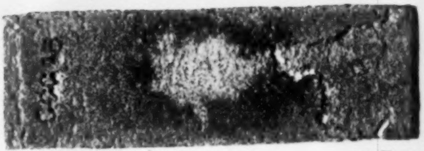


CC-22 Rack 6 139 Days

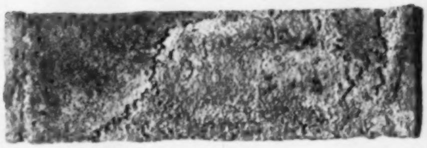
(*a*) Low-Copper Pure Iron
Average, 130 Days



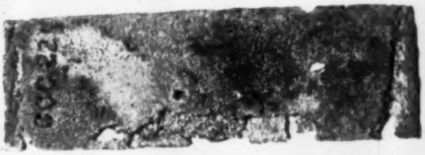
CCC-17 Rack 1 84 Days



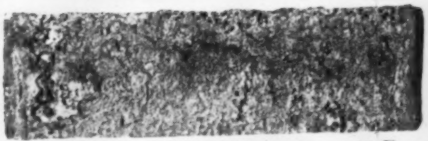
CCC-18 Rack 2 77 Days



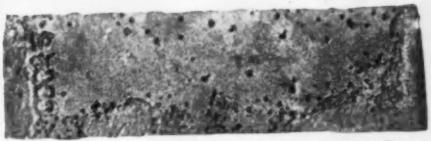
CCC-21 Rack 3 84 Days



CCC-22 Rack 4 98 Days



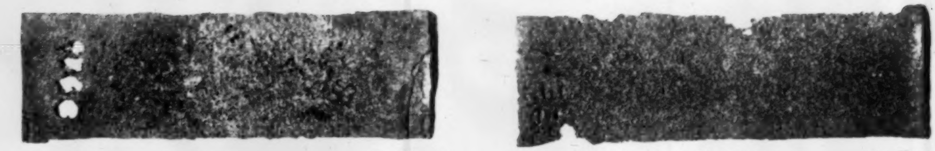
CCC-24 Rack 5 139 Days



CCC-25 Rack 6 112 Days

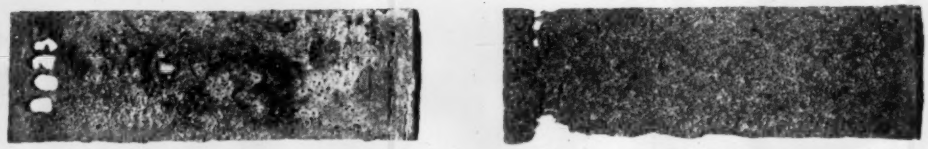
(*b*) Copper-Bearing Pure Iron
Average, 99 Days

FIG. 15.—Calumet Mine Water Test. No. 16 Gage.



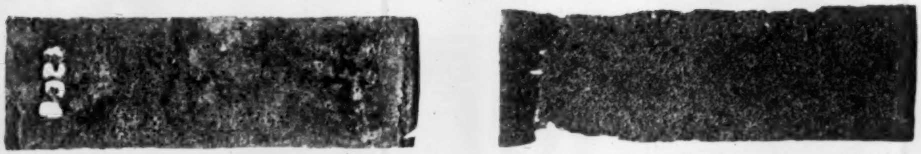
DD-24 Rack 1 98 Days

EE-11 Rack 1 98 Days



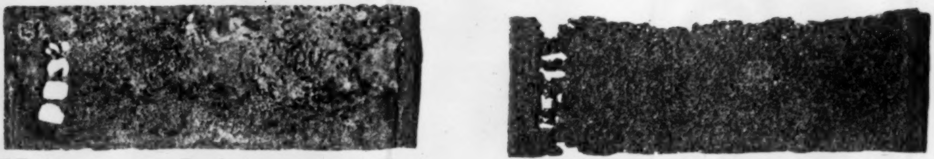
DD-26 Rack 2 98 Days

EE-13 Rack 2 98 Days



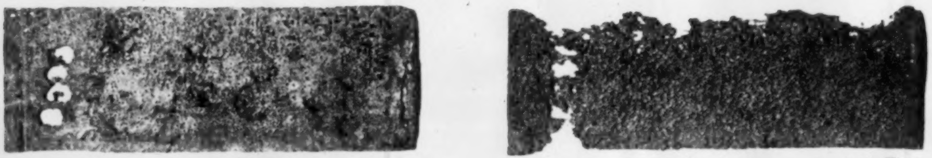
DD-28 Rack 3 112 Days

EE-15 Rack 3 125 Days



DD-32 Rack 4 125 Days

EE-16 Rack 4 153 Days



DD-35 Rack 5 112 Days

EE-17 Rack 5 153 Days

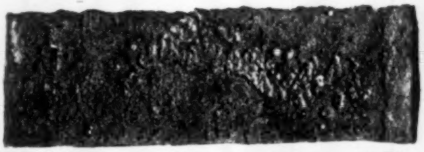
DD-40 Rack 6 112 Days

EE-20 Rack 9 139 Days

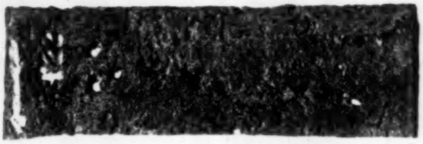
(*a*) Low-Copper Pure Iron
Average, 109.5 Days

(*b*) Copper-Bearing Puddle Iron
Average, 127.66 Days

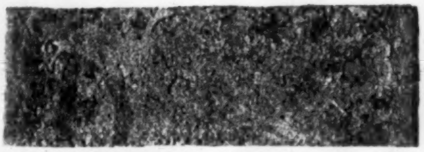
FIG. 16.—Calumet Mine Water Test. No. 16 Gage.



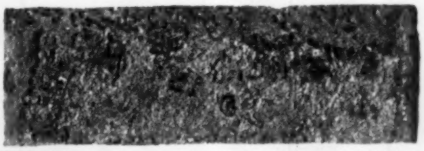
HH-20 Rack 1 77 Days



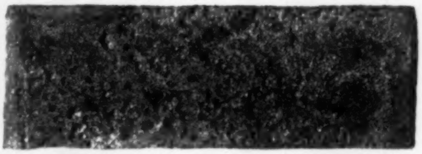
HH-22 Rack 2 98 Days



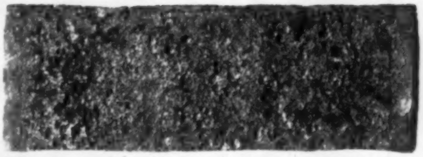
HH-26 Rack 3 112 Days



HH-28 Rack 4 125 Days

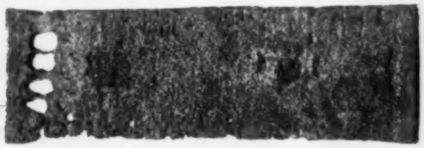


HH-32 Rack 5 112 Days

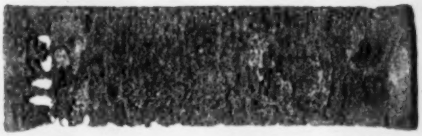


HH-34 Rack 6 125 Days

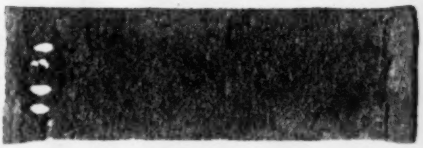
(*a*) Copper-Bearing Basic Open-Hearth Steel
Average, 108.16 Days



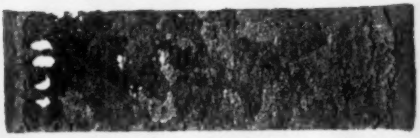
II-26 Rack 1 112 Days



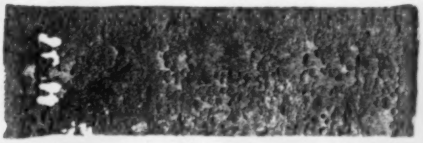
II-28 Rack 2 112 Days



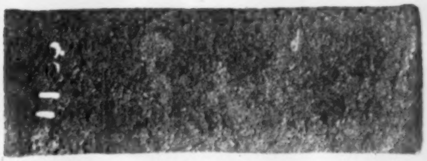
II-31 Rack 3 125 Days



II-33 Rack 4 139 Days



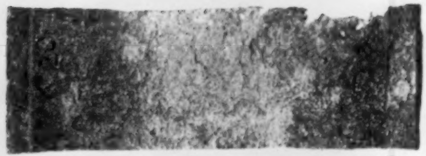
II-37 Rack 5 139 Days

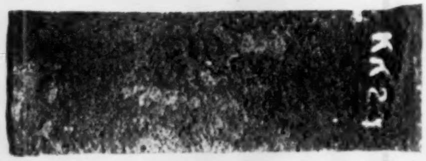


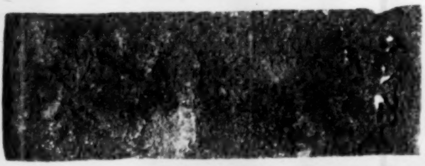
II-38 Rack 6 112 Days

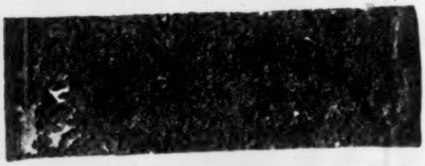
(*b*) Copper-Bearing Bessemer Steel
Average, 123.16 Days

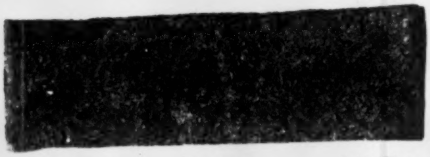
FIG. 17.—Calumet Mine Water Test. No. 16 Gage.


KK-20 Rack 1 98 Days


KK-23 Rack 2 112 Days

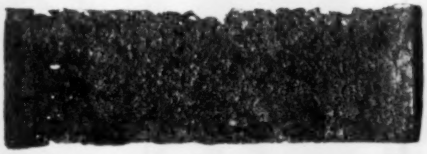

KK-26 Rack 3 84 Days

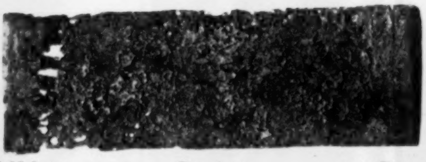

KK-30 Rack 4 125 Days

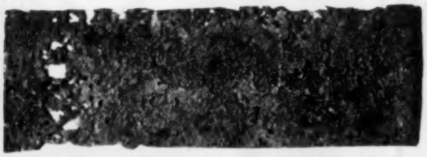

KK-32 Rack 5 125 Days

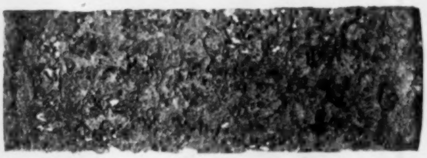
KK-34 Rack 6 112 Days

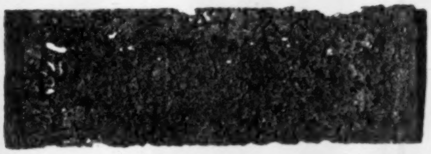
(*a*) Copper-Bearing Acid Open-Hearth Steel
Average, 109.33 Days

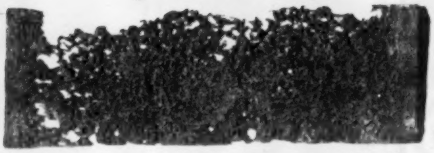

MM-16 Rack 1 98 Days


MM-18 Rack 2 112 Days


MM-20 Rack 3 112 Days

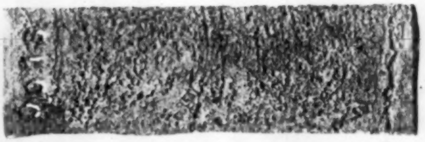

MM-22 Rack 4 125 Days


MM-27 Rack 5 139 Days

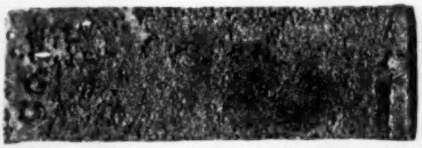

MM-29 Rack 6 139 Days

(*b*) Low-Copper Basic Open-Hearth Steel
Alan Wood Iron and Steel Co.
Average 120.83 Days

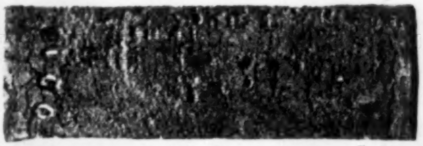
FIG. 18.—Calumet Mine Water Test. No. 16 Gage.



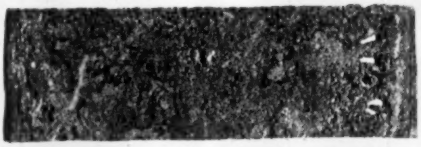
OO-13 Rack 1 112 Days



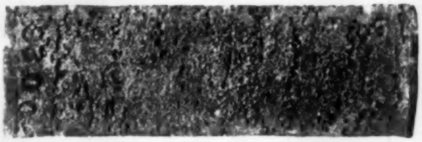
OO-14 Rack 2 98 Days



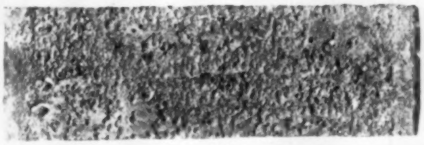
OO-15 Rack 3 98 Days



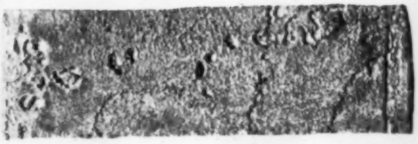
OO-17 Rack 4 112 Days



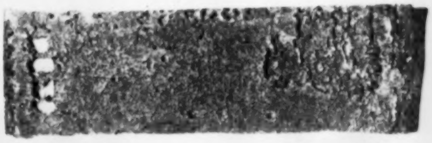
OO-28 Rack 5 112 Days



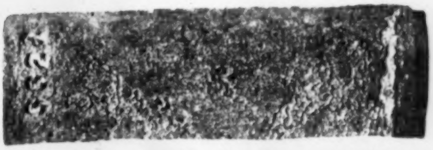
OO-30 Rack 6 112 Days



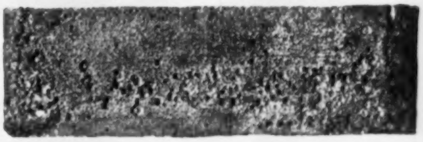
SS-19 Rack 1 98 Days



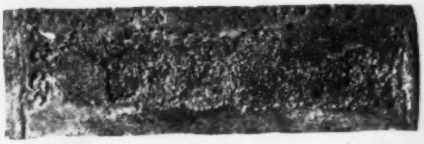
SS-21 Rack 2 125 Days



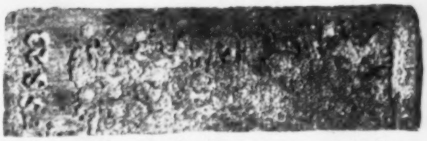
SS-22 Rack 3 125 Days



SS-25 Rack 4 112 Days



SS-27 Rack 5 139 Days

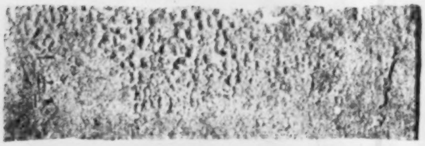


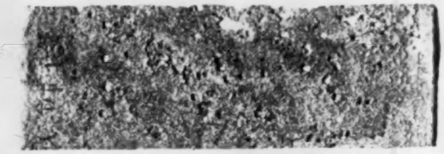
SS-28 Rack 6 139 Days

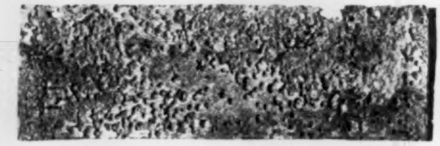
(*a*) Low-Copper Basic Open-Hearth Steel
Inland Steel Co.
Average, 107.33 Days

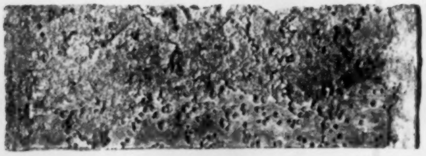
(*b*) Low-Copper Pure Iron
American Rolling Mill Co.
Average, 123 Days

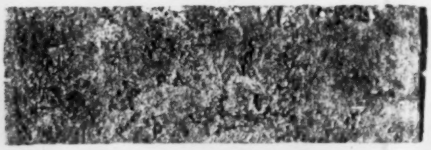
FIG. 19.—Calumet Mine Water Test. No. 16 Gage.

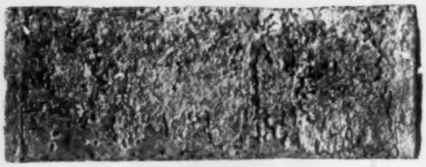

TT-13 Rack 1 77 Days

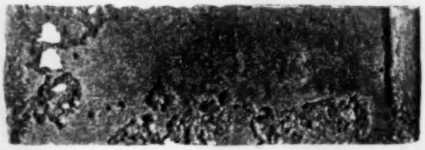

TT-15 Rack 2 98 Days

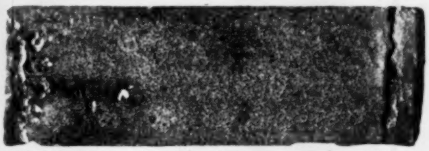

TT-16 Rack 3 98 Days

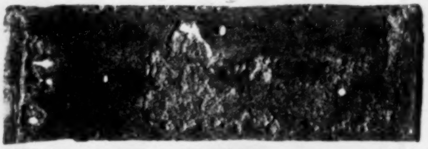

TT-18 Rack 4 98 Days

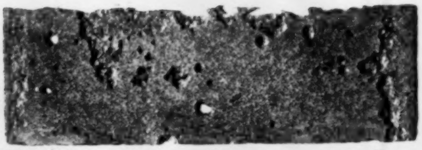

TT-21 Rack 5 98 Days

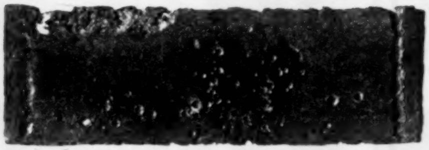

TT-24 Rack 6 112 Days

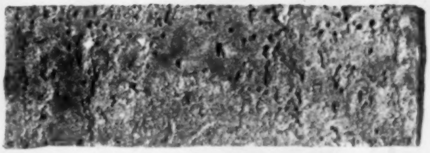

UU-11 Rack 1 98 Days


UU-13 Rack 2 49 Days


UU-16 Rack 3 98 Days


UU-18 Rack 4 77 Days


UU-21 Rack 5 112 Days


UU-24 Rack 6 112 Days

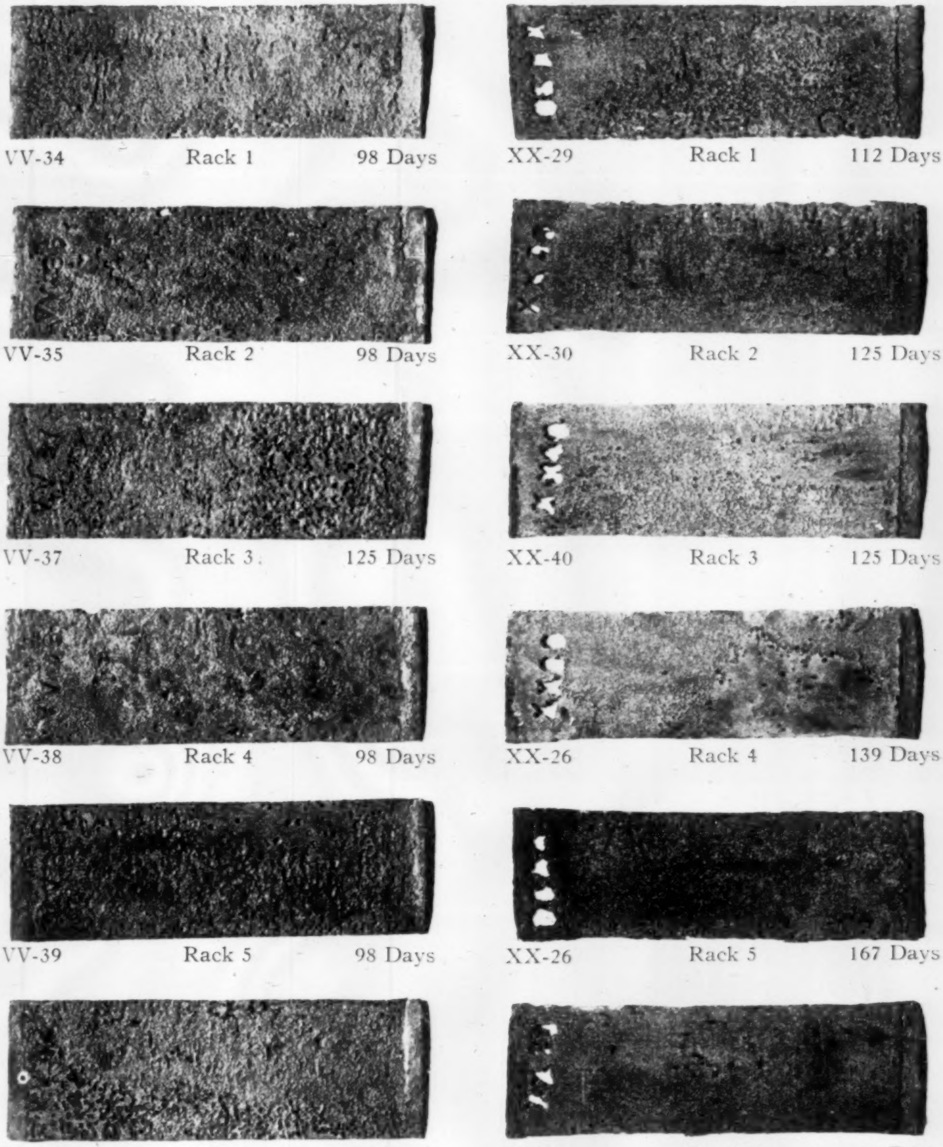
(*a*) Copper-Bearing Basic Open-Hearth Steel
Newport Rolling Mill Co.

Average, 96.83 Days

(*b*) Copper-Bearing Pure Iron
Allegheny Steel Co.

Average, 91 Days

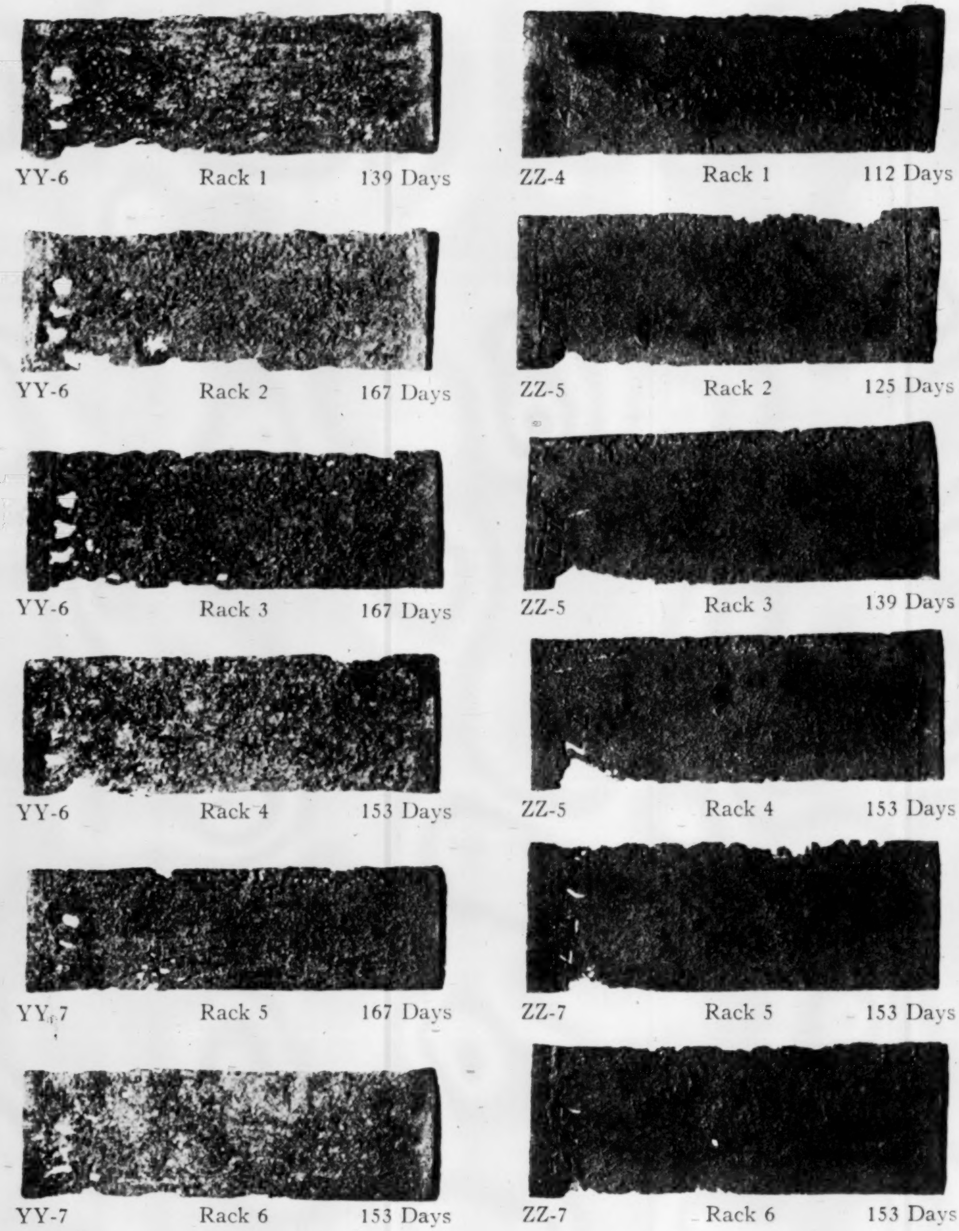
FIG. 20.—Calumet Mine Water Test. No. 16 Gage.


VV-34 Rack 1 98 Days
XX-29 Rack 1 112 Days
VV-35 Rack 2 98 Days
XX-30 Rack 2 125 Days
VV-37 Rack 3 125 Days
XX-40 Rack 3 125 Days
VV-38 Rack 4 98 Days
XX-26 Rack 4 139 Days
VV-39 Rack 5 98 Days
XX-26 Rack 5 167 Days
VV-42 Rack 6 125 Days
XX-28 Rack 6 139 Days

(*a*) Copper-Bearing Pure Iron
Whitaker-Glessner Co.
Average, 107 Days

(*b*) Low-Copper Pure Iron
Inland Steel Co.
Average, 134.5 Days

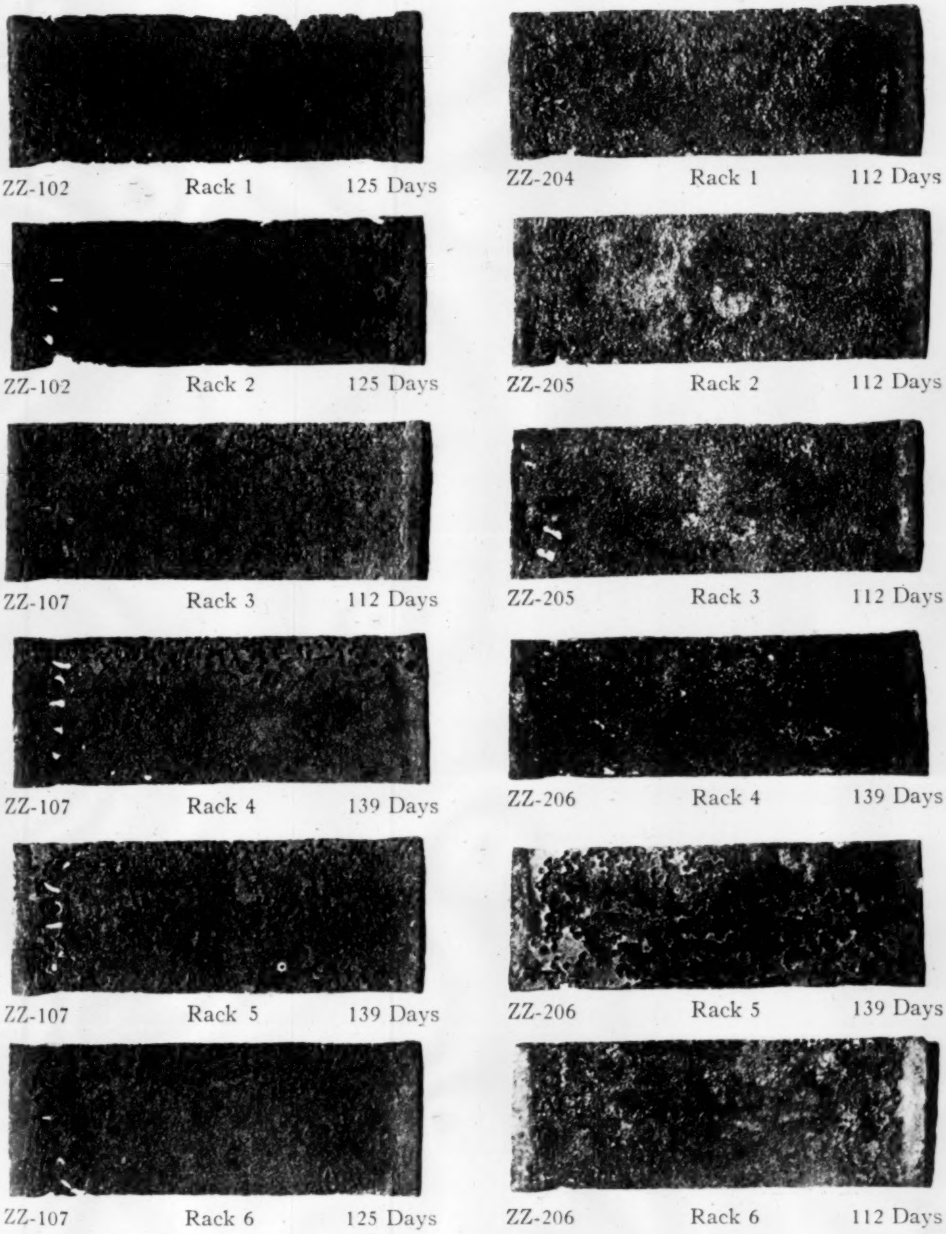
FIG. 21.—Calumet Mine Water Test. No. 16 Gage.


YY-6 Rack 1 139 Days
ZZ-4 Rack 1 112 Days
YY-6 Rack 2 167 Days
ZZ-5 Rack 2 125 Days
YY-6 Rack 3 167 Days
ZZ-5 Rack 3 139 Days
YY-6 Rack 4 153 Days
ZZ-5 Rack 4 153 Days
YY-7 Rack 5 167 Days
ZZ-7 Rack 5 153 Days
YY-7 Rack 6 153 Days
ZZ-7 Rack 6 153 Days

(*a*) Low-Copper Puddle Iron
Youngstown Sheet and Tube Co.
Average, 157.66 Days

(*b*) Low-Copper Bessemer Steel
Youngstown Sheet and Tube Co.
Average, 139.16 Days

FIG. 22.—Calumet Mine Water Test. No. 16 Gage.



ZZ-102 Rack 1 125 Days

ZZ-102 Rack 2 125 Days

ZZ-107 Rack 3 112 Days

ZZ-107 Rack 4 139 Days

ZZ-107 Rack 5 139 Days

ZZ-107 Rack 6 125 Days

(*a*) Copper-Bearing Bessemer Steel. Average Copper, 0.156
Average, 127.5 Days

ZZ-204 Rack 1 112 Days

ZZ-205 Rack 2 112 Days

ZZ-205 Rack 3 112 Days

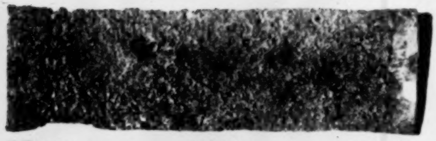
ZZ-206 Rack 4 139 Days

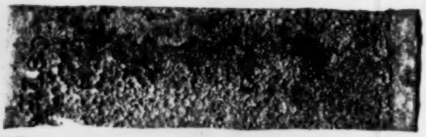
ZZ-206 Rack 5 139 Days

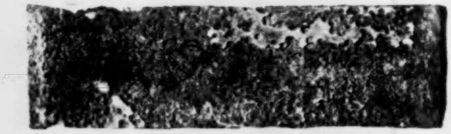
ZZ-206 Rack 6 112 Days

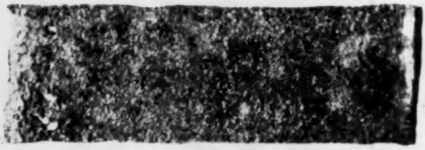
(*b*) Copper-Bearing Bessemer Steel. Average Copper, 0.284
Average, 121 Days

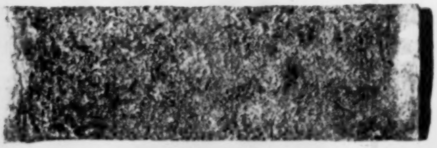
FIG. 23.—Calumet Mine Water Test. No. 16 Gage.

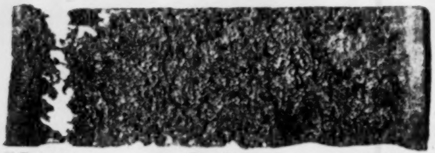

ZZ-308 Rack 1 112 Days


ZZ-308 Rack 2 112 Days

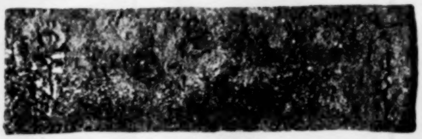

ZZ-308 Rack 3 125 Days


ZZ-309 Rack 4 125 Days

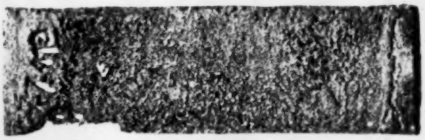

ZZ-309 Rack 5 125 Days

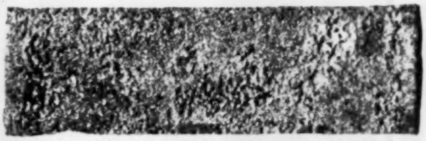

ZZ-309 Rack 6 153 Days

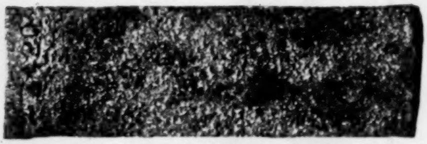
(*a*) Copper-Bearing Bessemer Steel. Average Copper, 0.528
Average, 125.33 Days


ZZ-419 Rack 1 98 Days

ZZ-419 Rack 2 112 Days


ZZ-419 Rack 3 125 Days

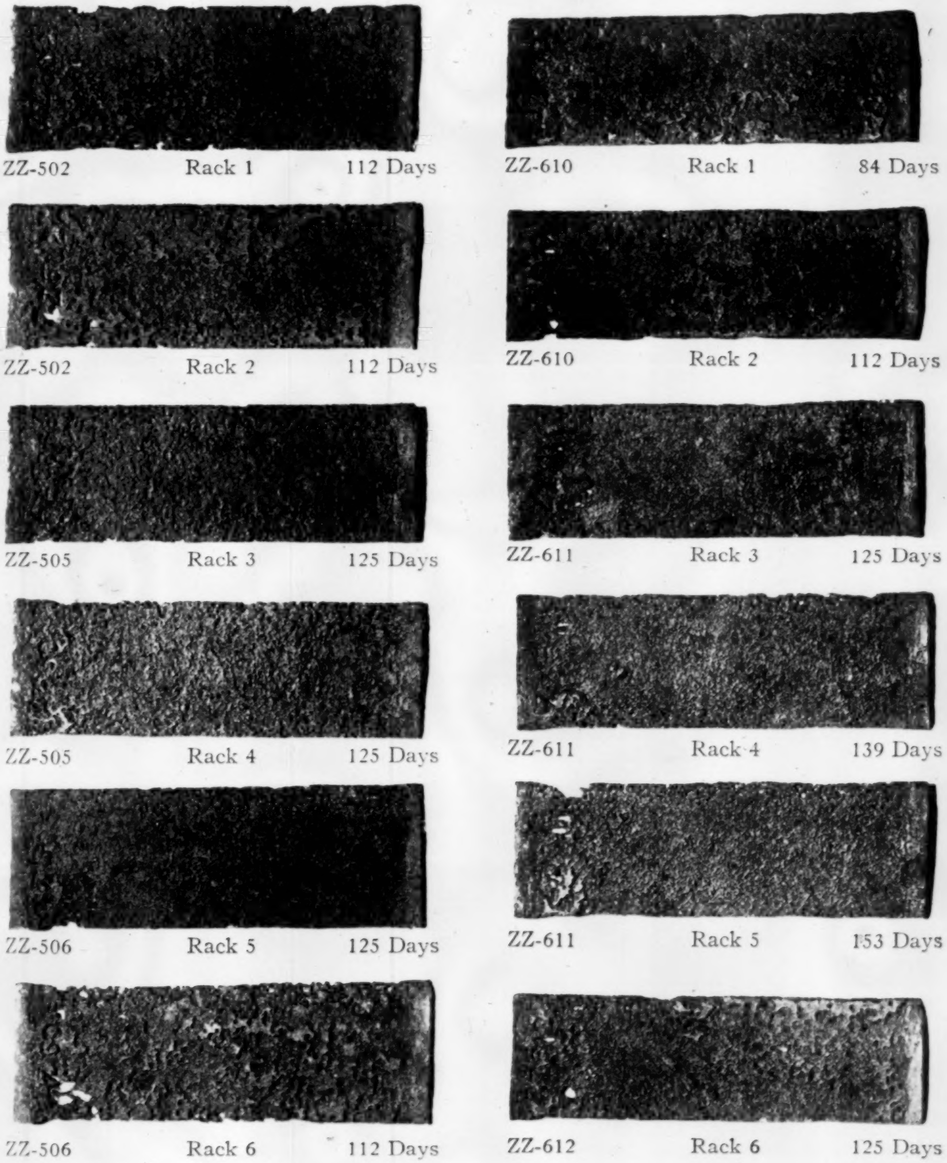

ZZ-420 Rack 4 125 Days


ZZ-420 Rack 5 125 Days

ZZ-420 Rack 6 125 Days

(*b*) Low-Copper Basic Open-Hearth Steel
Youngstown Sheet and Tube Co.
Average, 118.33 Days

FIG. 24.—Calumet Mine Water Test. No. 16 Gage.

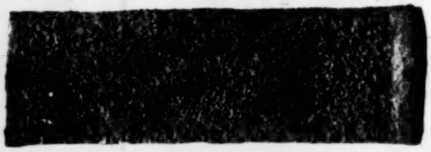

ZZ-502 Rack 1 112 Days
ZZ-610 Rack 1 84 Days
ZZ-502 Rack 2 112 Days
ZZ-610 Rack 2 112 Days
ZZ-505 Rack 3 125 Days
ZZ-611 Rack 3 125 Days
ZZ-505 Rack 4 125 Days
ZZ-611 Rack 4 139 Days
ZZ-506 Rack 5 125 Days
ZZ-611 Rack 5 153 Days
ZZ-506 Rack 6 112 Days
ZZ-612 Rack 6 125 Days

(*a*) Copper-Bearing Basic Open-Hearth Steel
Average Copper, 0.233
Average, 118.5 Days

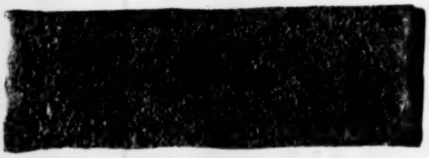
(*b*) Copper-Bearing Basic Open-Hearth Steel
Average Copper, 0.629
Average, 123 Days

FIG. 25.—Calumet Mine Water Test. No. 16 Gage.

ZZ-711 Rack 1 112 Days



ZZ-712 Rack 2 112 Days



ZZ-712 Rack 3 112 Days

ZZ-712 Rack 4 112 Days

ZZ-713 Rack 5 139 Days

ZZ-713 Rack 6 125 Days

Copper-Bearing Basic Open-Hearth Steel. Average Copper, 0.328
Average, 118.66 Days
FIG. 26.—Calumet Mine Water Test. No. 16 Gage.

DISCUSSION.

Mr. Aupperle.

MR. J. A. AUPPERLE (*presented in written form*).—If the atmospheric tests at Pittsburgh have told their story as to what can be expected from bare, uncoated sheets exposed to the atmosphere, we must be careful not to draw conclusions as to the deportment of the various ferrous metals when subjected to different service conditions. This is of great importance, for when comparing the results obtained in the atmospheric tests with the results obtained in the mine water tests, we find a very pronounced difference in the behavior of the various types of metals. For instance, we find that in Table XII of the report, the numerical grade given to the Copper-Bearing Bessemer Sheets, Group Designation: I, is higher than the numerical grade given to any other material exposed in the atmospheric test, and by curious coincidence we find that portions of the very same sheets when placed in mine water were the first to fail. On the other hand, we find that the Bessemer Steel, free from copper, which failed first in the atmospheric test at Pittsburgh, when subjected to the action of mine water, lasted for a greater average length of time than copper-bearing metal.

The photographs of the mine water tests show that the Copper-Bearing Steel has pitted to a greater extent than iron and steel low in copper.

If we consider the mine water test by the number of days, we find the No. 22 gage material falls in three groups of 28 days, 35 days, and 42 days. Those which failed in 28 days included four copper-bearing metals and two low-copper metals. In the 35-day period, failures occurred on most grades of material with the exception of the low-copper Pure Iron sheets (Group Designations: S and D), which did not fail until the 42-day period. The photographs of these immersion tests show the "S" and "D" Pure Iron sheets to be in much better condition than the copper-bearing sheets.

Let us consider the deportment of Puddled Iron sheets (Group Designations: E and Y); one containing high and the other low copper. We find that in the atmosphere at Pittsburgh the high-copper puddled-iron sheets failed in 22 months, and the low-copper puddled iron sheets failed in 28 months. From the results of this atmospheric test we would infer that copper-bearing puddled iron would not be a good metal to use, as it was among the first to fail in

Mr. Aupperle. this location. We would also infer that the low-copper puddled iron would not give good results, whereas actual service tests of material of similar analysis has shown such metals to be extremely durable.

These accelerated tests have not told their story as has been intimated, for these tests obviously condemn iron with and without copper, whereas it is a well-known fact that under many diverse service conditions these irons have outlasted steel.

We all know of the many good results which have been obtained from the use of concrete under many different service conditions, and no one would think of condemning concrete for general purposes on account of its failure under certain specific conditions. On page 29 in a report by Dalton G. Miller of the Bureau of Public Roads which covered Field Investigations of Concrete Tile Failures in Southwestern Minnesota, Mr. Miller makes the following remarks:

> "Distinct evidence of disintegration (of concrete tile) was noted where the salt content of the soil water analyzed but 1443 parts per million of salts, as evidenced by the failure at Station 36 on Branch 1 of Lyon County, Drain No. 16. This result is somewhat complicated from the fact that the drain water in the tile at this point showed a higher concentration and analyzed 1848 P. P. M. of salts. Tile here had been in ground three years.
>
> "One outstanding fact is evident from these investigations, and that is that the concrete tile as at present manufactured and used in this area in localities in which sulphate waters predominate have not stood up under the more severe conditions of alkalinity to which they have been subjected, subsequent to installation, as evidenced by the many failures in Lyon County, all of which have occurred in drains within 4 years after completion."

In "The Reclamation Record" of May, 1921, reference is made to the failure of concrete as follows:

> "While the Denver blocks have generally been more resistant to alkali than the blocks molded on the projects, they have been seriously affected where concentrations have been high, and on one project all blocks installed may be considered as complete failures.
>
> "Summing up, our experiments seem to indicate that surface disintegration of the poorer grades of concrete begins with concentrations of about two-tenths of 1 per cent in waters of the sulphate type, and that the severity of the action increases *as concentration of salts increases until with concentrations of 2 to 3 per cent even the best concrete disintegrates rapidly.*"

Mr. Aupperle. In like manner we should not condemn any iron or steel which failed in these tests, if such material is to be used for service conditions which have no relation to such tests.

For example, we should not be too hasty in drawing the conclusion that material which has failed first in the Pittsburgh atmosphere will also fail first when used for smokestacks, for the service conditions are not the same. In the case of a smokestack, we may have reducing or oxidizing conditions. If reducing, then any ferrous sulfate which may have formed would attack the copper-bearing steel more rapidly than Pure Iron. If the conditions are oxidizing then the adherence of the oxide plays an important part, the oxide adhering much better to iron at high temperatures than to steel, the adhering oxide protecting the base metal. This has been confirmed by J. J. Tatum, Superintendent of the Car Department of the Baltimore and Ohio Railroad, in the *Railway Review* of May 7, 1921. Mr. Tatum refers to a smokestack which was removed from an old rolling mill at Cumberland, Md. The stack was placed in use about 40 years ago and showed practically no deterioration, yet it was exposed to the elements and sulfuric acid supplied by heavy atmosphere at a large railroad terminal. Mr. Tatum has also shown that iron box cars show very little deterioration after 60 years' service.

I have analyzed iron from the Gunboat Merrimac, which was in a very good state of preservation after having been in salt water for more than half a century. I have also analyzed iron nails which were in the ground for 100 years. In these instances I found that the iron was similar in analysis to material which failed first in the Pittsburgh atmospheric test.

Another example of the durability of iron is the old powder car referred to in the *Railway Review*, of June 12, 1920. This car has been in more or less continuous service for the last 60 years. The car was originally constructed for the transportation of explosives by the Union armies during the Civil War, and has a greater mileage than any other car in its company's service. During the war the car was dumped into the Etowah River, it later being removed from the river and placed in service by the N. C. and St. L. Ry. These are interesting examples of the durability of iron and Table I will show how closely they resemble the iron which failed first in the atmospheric test at Pittsburgh, thus showing that no conclusions can be drawn from atmospheric tests when the metal is to be used for smokestacks or freight cars.

Mr. Tatum has shown that steel car floors are renewed in less

Mr. Aupperle. than 15 years and sides in less than 18 years, whereas the two iron cars referred to lasted for more than 60 years.

I have shown that under certain conditions concrete culverts fail in from 3 to 4 years. This does not mean that concrete should be condemned for other purposes where it has been found to be giving satisfactory service.

In summing up the atmospheric tests and mine water tests, we find that low-copper material which failed first in the atmosphere, lasted longest when subjected to the action of mine water. We also find that copper-bearing sheets which received the highest grade in the atmospheric tests were among the first to fail in the mine water tests. I have also shown that material which failed first in the Pittsburgh atmosphere is of a similar analysis to material which has given exceptionally long service when used for cars, smokestacks and gunboats.

TABLE I.

	Copper, per cent.	Sulfur, per cent.	Phosphorus, per cent.	Carbon, per cent.	Manganese, per cent.	Silicon, per cent.
Iron box car, B. and O. R. R., in service 60 years, similar in analysis to "E" sheets, A.S.T.M. tests	0.540	0.020	0.034	low	none	.....
Iron smokestack, in service 40 years at Cumberland, Md., similar in analysis to "E" sheets, A.S.T.M. tests	0.440	0.030	0.177	0.012	0.05	.....
High-copper iron, sheets "E", A.S.T.M. tests, failed in Pittsburgh atmosphere in 22 months	0.283	0.021	0.114	0.033	0.034	0.134
Iron powder car, N. C. and St. L. R. R., in service 60 years, similar in analysis to "Y" sheets, A.S.T.M. tests	trace	0.042	0.332	0.024	0.048	0.210
Iron from Gunboat Merrimac, in salt water half a century, similar in analysis to "Y" sheets, A.S.T.M. tests	0.018	0.016	0.007	0.022	0.010	0.038
Low-copper iron sheets "Y", A.S.T.M. tests, failed in Pittsburgh atmosphere in 28 months	0.020	0.021	0.139	0.030	0.055	0.218
Low-copper Bessemer steel, "A" sheets, first to fail in Pittsburgh atmosphere, last to fail in mine water	0.012	0.039	0.086	0.043	0.388	0.012
High-copper Bessemer steel, "I" sheets, last to fail in Pittsburgh atmosphere, first to fail in mine water	0.261	0.069	0.093	0.030	0.372	0.009

REPORT OF COMMITTEE B-1
ON
COPPER WIRE.

In 1919, Committee B-1 presented for publication as tentative Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 – 19 T)[1] and gave notice that when these specifications are advanced to standard, modifications would be necessary in the Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (B 8 – 16).[2]

Specifications B 33 – 19 T have now been in practical use for about two years and there has been no indication that modifications are desirable or necessary. The committee, however, calls attention to two errors which should be corrected, viz:

1. The resistivity of size 0.011 to 0.003 in. is given in Table II as 938.20 lb. per mile ohm, whereas it should be 939.51.

2. The specific gravity of the hydrochloric acid solution is stated in Section 9 (*a*) as 1.008, whereas it obviously should be 1.088.

With these two errors corrected your committee recommends that the Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (B 33 – 19 T) be submitted to letter ballot of the Society for adoption as standard.

At the solicitation of Committee D-11 on Rubber Products, consideration has been given to the question of testing wire removed from completed cable. It has been claimed that it is not always possible to test the wire before stranding and some test on the wires composing the cable is greatly to be desired. After mature consideration, Committee B-1 has reached the conclusion that when cable is made of soft bare or soft tinned wire, it is safely possible to provide for test on wires removed for this purpose from cable and has agreed upon the necessary modifications of the physical properties expected of such wires as compared with the properties required of the wires before cabling. The committee reaffirms its earlier report that the attempt to unwind and straighten hard or medium hard wire removed from cable to prepare it for testing so distorts and deforms the wire as to amount to actual damage. Tests made on such deformed wires yield no useful indication either of the properties of the cable or of the wires forming the cable.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 574 (1920).

[2] 1918 Book of A.S.T.M. Standards.

Your committee, therefore, proposes the following revisions of the Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft (B 8 – 16):[1]

1. *Section 2.*—Change to read as follows by the addition of the italicized words and figures and the omission of the words in brackets:

> "The copper wires entering into the construction of standard concentric-lay cable shall, before stranding, meet all the requirements of that one of the Standard Specifications of the American Society for Testing Materials for Hard-Drawn, Medium Hard-Drawn, [or] Soft or Annealed ***or Tinned Soft*** Copper Wire (Serial Designations: B 1, B 2, [or] B 3 ***or B 33***), which applies."

2. *Section 5.*—Change from its present form, namely:

> "Tests for the physical and electrical properties of the wires composing the cables may be made before, but not after, stranding. Experience indicates that the tensile strength of concentric-lay copper cable of standard pitch is at least 90 per cent of the total strength required of the wires forming the cable."

to read as follows:

> "(*a*) Tests for the physical and electrical properties of the wires composing cables made from hard-drawn or medium hard-drawn wire may be made before but not after stranding.
>
> "(*b*) Tests for the physical and electrical properties of wires composing cables made from annealed copper wire or from tinned soft copper wire may be made on wires removed from the cable in which case the maximum tensile strength permitted shall be increased 5 per cent and the minimum elongation permitted shall be reduced 5 per cent. Care must be taken to avoid mechanical injury of wire removed from cable for the purpose of testing.
>
> "(*c*) Experience indicates that the tensile strength of concentric-lay copper cable of standard pitch is at least 90 per cent of the total strength required of the wires forming the cable."

3. *Section 10* (*a*).—Change the second sentence to read as follows by the addition of the italicized words:

> "Tests on individual wires shall be made on samples taken before cabling and not on wires removed from the completed cable ***except as provided in Section 5 (b).***"

The committee recommends that these revisions be adopted and the specifications B 8 – 16 as amended continued as standard.

Committee B-1 has been working in cooperation with Committee D-11 on Rubber Products whose Sub-Committee on Insulated Wires has prepared specifications for rubber-covered tinned wire and cable. In these specifications the requirements for the copper wire appear to be somewhat different from those in the specifications of Committee B-1. As the result of conferences between the two committees, it became evident that some of these differences were apparent rather than real, and that they were the result of different methods of statement. Some of the differences were real and were justified by the fact that the two products covered are essentially different products; the processes of insulating modify the properties of the original wires so that rubber-covered wire or cable should be expected to yield somewhat different results upon test. Unjustified differences between the work of the two committees were adjusted and the specifications presented at the annual meeting are satisfactorily in agreement.

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[1] 1918 Book of A.S.T.M. Standards.

A general standardization of wires and cables for electrical conductors has been proposed under the auspices of the American Engineering Standards Committee. Our Society is cooperating in this work and Committee B-1 is represented.

The two recommendations contained in this report were submitted to letter ballot of the committee, and 9 members voted affirmatively and 1 refrained from voting.

This report has been submitted to letter ballot of the committee which consists of 10 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of committee,

J. A. CAPP,
Chairman.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium-Hard or Soft referred to in this report were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The specifications as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The Tentative Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation as amended were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE B-2
ON
NON-FERROUS METALS AND ALLOYS.

The work of Committee B-2 during the past year consisted in the preparation of specifications covering nickel and of methods for the chemical analysis of nickel and of aluminum and light aluminum alloys. The following reports covering the activities of the various sub-committees were accepted at the last meeting of the committee on April 11, 1921.

SUB-COMMITTEE I ON PURE METALS IN INGOT FORM.

The chairman, Mr. Bassett, presented tentative specifications for nickel which are appended[1] to this report.

The sub-committee had contemplated revising the Tentative Specifications for Pig Lead (B 29 – 20 T) so as to provide separate chemical requirements for high-bismuth corroding lead and low-bismuth corroding lead. The sub-committee is not prepared to make any definite recommendation in regard to such revision, however, and so recommends that the specifications be continued as tentative for another year without revision.

In this regard the following notes on the available supply of the various grades of pig lead are of interest.

For the ten years ending December 31, 1920, the production of Pig Lead in the United States from foreign and domestic ores averaged 559,000 tons per annum.

This production can be divided into the following classes:

DOMESTIC.		
Desilverized (corroding and common desilverized)	273 000	tons
Southeast Missouri (chemical lead)	176 000	"
Southwest Missouri (soft Missouri lead)	33 000	"
Antimonial lead (not covered by these specifications)	16 000	"
Total	498 000	"
FOREIGN.		
Desilverized	58 000	tons
Antimonial	3 000	"
Total	61 000	"
Grand total	559 000	"

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[1] See p. 495.—ED.

Corroding Lead.—The greatest use for Pig Lead in the United States is for the manufacture of paint pigments.

As the production of low bismuth corroding lead is insufficient to fill this demand, and as there are consumers who prefer low bismuth corroding lead for purposes other than the manufacture of paint pigments, corroders to obtain the benefit of a broad market should take quotations on both grades of corroding lead.

Chemical Lead.—Of the Southeast Missouri Lead ore from which chemical lead is produced about one-third is refined by the Parkes process and thereby made into a high grade low bismuth corroding lead over 99.99 per cent pure.

More than 100,000 tons of chemical lead are used annually by the manufacturers of acid resisting sheet lead, storage batteries, lead encased cable, lead pipe traps and bends, etc., and in the Central Freight Association Territory, where the freight rates are favorable, to users of common lead.

It is general practice in this country to use the Southeast Missouri or Chemical Lead where acid resisting qualities are required. In some of the other English speaking countries lead of high purity such as that obtained by refining Southeast Missouri lead by the Parkes process seems to be preferred for this purpose.

Soft Missouri Lead.—The production of this grade is comparatively small, and its use is largely confined to the St. Louis and Chicago districts.

Desilverized Lead.—As all grades of lead are desilverized with the exception of chemical and soft Missouri Lead, this class would cover all other grades of lead not pure enough to be sold under corroding specifications.

SUB-COMMITTEE II ON WROUGHT METALS AND ALLOYS.

Mr. W. R. Webster, chairman, reported that his sub-committee recommends that the Tentative Specification for Sheet High Brass (B 36 – 20 T)[1] be made standard.

In Specification for Free-Cutting Brass Rod for use in Screw Machines (B 16 – 18)[2] there is an error which ought to be corrected. In Section 6 the diameter of the pin is given as equal to the diameter of the bar whereas it ought to be equal to twice the diameter of the bar, following the various specifications of Committee A-1. As this is a correction and not a change, according to the rules of the Society it may be approved now without being held tentative for one year.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 580 (1920).

[2] 1918 Book of A.S.T.M. Standards.

SUB-COMMITTEE III ON SAND CAST METALS AND ALLOYS.

Mr. Corse reported that Sub-Committee III recommended that the Tentative Specifications for Bronze Bearing Metals for Turntables and Movable Railroad Bridges (B 22 – 18 T)[1] and the Tentative Specifications for Bronze Bearing Metal in Ingot Form (B 31 – 19 T)[2] be made standard. In the appendix to this latter specification, figures are given for the Compression Elastic Limit, in pounds per square inch on samples 1 sq. in. in sectional area and 1 in. high. Criticisms have been made because this size of test specimen does not conform to those recommended in the Standard Methods of Testing (E 1 – 18) of the Society. Again, the elastic limit defined as the load producing a compression in the specimen of 0.001 in. does not correspond to elastic limit as defined in the standard methods. It is therefore, recommended that this column of the table be revised to give compression yield point on cylindrical specimens of 1 sq. in. in sectional area and 3 in. high and the yield point to be determined as defined in the standard methods of testing. The revision of the figures was referred to Committee E-1.

In regard to the Tentative Specifications for Brass Ingot Metal for Sand Castings (B 30 – 19 T)[3] the following changes are proposed:

Change the title of the specifications to read "Tentative Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings."

Section 1.—Add a sentence to read as follows:

"These specifications also cover brass ingot metal which has no grade limit, designated as ungraded material such as a specific lot of ingots having a stated composition suitable for the buyers' needs."

Section 2.—Add a sentence to read as follows:

"Individual ingots of any lot shall not show an extreme variation between the high and low copper percentages of more than 2.5 per cent and between the high and low percentages of the other main constituents, except zinc, of more than 1.5 per cent."

Section 3.—Insert the word "graded" before the word "alloys" in the first line of Section 3.

In the table of requirements for chemical composition change the requirements for copper for Alloy, Grade No. 1 from 86 per cent to 87 per cent and the requirements for lead from 3 per cent to 2 per cent.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 533 (1920)

[2] *Ibid.*, p. 565.

[3] *Ibid.*, p. 561.

Section 4.—Change the table of permissible variations by the addition of the italicized figures and the omission of the figures in brackets:

Percentage of Element Specified.	Permissible Variations Over and Under the Specified Value, Units of Per Cent.
Not over 5 per cent	0.50
Over 5 to [10] *15* per cent, incl	0.75
Over [10] *15* per cent	1.00

Section 5. (a).—Change from its present form: namely,

> "Three ingots shall be selected by the inspector to represent 10,000 lb. of ingot or fraction thereof."

to read as follows:

> "Ten ingots shall be selected by the inspector to represent a minimum carload or over approximating 40,000 lb. and five ingots for less than carload lots."

In the table given in the appendix change the percentage of copper under Alloy, Grade No. 1 from 86 per cent to 87 per cent and the percentage of lead from 3 per cent to 2 per cent. In the column headed "Examples of Uses" change the use given for the Alloy, Grade No. 4 from "Small valves and fittings" to read "valves and fittings for low pressure."

Sub-Committee IV on White Metals.—Mr. G. H. Clamer, chairman, reported that this sub-committee requests that the Tentative Specifications for Solder Metal (B 32 - 19 T)[1] be made standard. In regard to the Tentative Specification for White Metal Bearing Alloys (B 23 - 18 T) it is recommended they be held tentative for another year. In the appendix to this Tentative Specification a table showing the physical properties of White Metal Bearing Alloys is given. The figures for Brinell Hardness require revision and this will be made by Dr. Burgess. Again, the specimen for determination of deformation under compression does not conform to the size recommended by the Society in the Standard Methods of Testing (E 1 - 18). Also, it would seem preferable to give the yield point, ultimate compressive strength, etc., rather than the actual deformations which take place under definite loads. It is hoped therefore, that a complete revision of this table will be made during the coming year by Dr. Burgess. As the table now reads, there ought to be a footnote stating that the loads applied are total loads and that the deformation of the cylinder is measured in its full length. Also, that for Brinell Hardness the diameter of the steel ball was 10 mm. under a load of 300 kg. for 30 seconds.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 569 (1920).

SUB-COMMITTEE V ON PLATES, TUBES AND STAYBOLTS FOR LOCOMOTIVES.

Mr. Webster, chairman, reported that a criticism of the Standard Specifications for Copper Plates for Locomotive Fire Boxes (B 11 – 18)[1] and the Standard Specifications for Copper Bars for Locomotive Staybolts (B 12 – 18)[1] had been received on April 7, 1921, too late for consideration by the sub-committee. It related to the percentage elongation requirements for plates and for staybolt rods. The American Locomotive Co's. specifications call for elongations of 40 and 45 per cent, respectively, both for arsenical and non-arsenical copper.

	B 11 – 18.		AMERICAN LOCOMOTIVE CO.
	ARSENICAL.	NON-ARSENICAL	
Plates:			
Tensile strength, lb. per sq. in. . .	31 000	30 000	30 000
Elongation in 8 in., per cent	35	30	40
	B 12 – 18.		
Staybolts:			
Tensile strength, lb. per sq. in. . .	31 000	30 000	30 000
Elongation in 8 in., per cent	35	30	45

It was claimed that copper showing only 30 per cent elongation not infrequently worked poorly and was unsatisfactory, and that 40 and 45 per cent elongation were easily obtained when the metal was annealed at the correct temperature. The matter was referred back to the sub-committee with the request that suitable tests be made to settle this point in time to report on the question at the annual meeting of the Society.[2]

SUB-COMMITTEE VI ON NON-FERROUS ALLOYS FOR RAILROAD EQUIPMENT.

The Tentative Specifications for Non-Ferrous Alloys for Railway Equipment (B 17 – 18 T)[3] have been criticized and it is hoped by consultation with the Committee on Specifications of the American Railroads Association an acceptable specification will finally be agreed upon.

As these specifications have thus far been little used by the American railroads, but have been by foreign buyers of railroad equipment in this country, some confusion has arisen through the option given by foot-note *b* relating to phosphorus in the Bearing Metals. It was therefore, proposed to eliminate foot-note *b*, thus making phosphorus an impurity and to raise the allowable impurities including zinc to 2 per cent in Bearing Metals Nos. 1 and 2. After much discussion it was decided to refer the matter back to the sub-committee, asking it if possible to make such changes in composition that will give an acceptable specification to all concerned, in time for the June meeting.[1]

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[1] 1918 Book of A.S.T.M. Standards.

[2] The question of revising the elongation requirements in the Standard Specifications above referred to was considered by Sub-Committee V, but no definite recommendations could be made at the annual meeting of the Society.—ED.

[3] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 528 (1920).

SUB-COMMITTEE VII ON METHODS OF CHEMICAL ANALYSIS.

The work, consisting largely in critical examination of methods of analysis, has been chiefly carried out by correspondence.

Following the 1920 report of Committee B-2, the Methods for Analysis of Spelter have been re-written to conform in style and arrangement to other Methods of the Society, and the proposed foot-note[2] added. The Methods revised in this way will be published in the 1921 Book of A.S.T.M. Standards.

The sub-committee recommends that the present Tentative Methods for Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper, (B 18 - 20 T)[3] be adopted as standard.

Since these methods were proposed to be used particularly in connection with the Tentative Specifications for White Metal Bearing Alloys (B 23 - 18 T) it is recommended that a correction be made by the addition of a note to the title of the methods of analysis, as follows:

> "These methods apply particularly to White Metal Bearing Alloys (known commercially as 'Babbitt Metal'), and to similar lead and tin base alloys."

A correction is also to be made in directions for use of wash water for sulfide precipitates as given on page 591, Vol. XX, Part I of the Proceedings, consisting in directing that the wash water shall be saturated with hydrogen sulfide. These changes make absolutely no essential difference in the methods, and we believe can be introduced without affecting their adoption as standard at this time.

On page 44 of the pamphlet A.S.T.M. Standards Adopted in 1919, in the Standard Methods for Chemical Analysis of Gun Metal, the figure 0.01 should be changed to 0.02 in the first line just preceding the paragraph on Accuracy. This is the correction of an error in calculation.

Methods of Analysis of Aluminum and Light Aluminum Alloys.—Mr. Jesse L. Jones, chairman of Sub-Committee VIII, submitted to

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[1] See Addendum, p. 208.—ED.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 236 (1920).

[3] *Ibid.*, p. 589.

Sub-Committee VII Methods of Analysis of Aluminum and Light Aluminum Alloys, as published by the Aluminum Co. of America. These were forwarded to members of the sub-committee, and comments and criticisms were received. Using all of this material as a basis, Mr. G. E. F. Lundell, of the Bureau of Standards, made a revised draft of the methods in the style and arrangement uniform with other methods of the Society. This revised draft has been submitted to members of the sub-committee, and further changes suggested. In the meeting of the sub-committee, above referred to at which all members were present, all points brought up were considered in detail, and the sub-committee recommends that the Tentative Method of Analysis of Aluminum and Light Aluminum Alloys be approved and published as tentative as appended hereto.[1]

Method of Analysis of Nickel.—Mr. W. H. Bassett, chairman of Sub-Committee I, submitted to Sub-Committee VII Methods for Analysis of Nickel as proposed by Mr. J. F. Thompson of the International Nickel Co. Copy of these methods have been forwarded to all members of the sub-committee, and comments and criticisms received. These do not consist in any essential changes, so Mr. Thompson has revised the methods so that they will conform in style and arrangement to other methods of the Society, taking into consideration the comments and criticisms received as far as they do not conflict with the requirements particularly applicable to the analysis of this material.

It is recommended that the Tentative Methods of Analysis of Nickel, as appended hereto,[2] be approved and published as tentative.

SUB-COMMITTEE VIII ON ALUMINUM ALLOYS, CAST AND WROUGHT.

Mr. J. L. Jones, the chairman, reported that the work of the sub-committee during the past year consisted chiefly in obtaining methods of chemical analysis of aluminum and aluminum alloys for the sub-committee on Methods of Chemical Analysis. Work has been commenced along the line of co-defining the hardness of aluminum sheets and determining the Brinell Hardness and Scleroscope figures with their relation to the other physical properties. All of these factors are employed by different buyers for indicating the required quality of sheet and considerable misunderstanding arises because of the diversity of the nomenclature.

The sub-committee recommends that the Tentative Specification for Light Aluminum Casting Alloys (B 26 - 19 T)[1] be made standard and that the following specifications be held tentative for another year:

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[1] See p. 499.—ED.

[2] See p. 522.—ED.

For Aluminum Ingots for Remelting and for Rolling (B 24 - 20 T).
For Aluminum Sheet (B 25 - 19 T).
For Aluminum for use in the Manufacture of Iron and Steel (B 37 - 20 T).

In regard to the latter there is a typographical error on the top of page 587 in the Proceedings for 1920, Part I. Under 94.0-per-cent grade the percentage of aluminum is given as 98. This, of course, should read 94 per cent and the necessary steps have been taken to correct this error.

During the coming year it is hoped that work may be undertaken on light alloys both wrought and cast subject to heat treatment.

SUB-COMMITTEE IX ON NOMENCLATURE.

During August, 1920, the Secretary-Treasurer of the Society submitted copies of the report of Sub-Committee IX to the following organizations:

American Electrochemical Society;
American Institute of Chemical Engineers;
American Institute of Mining Engineers;
American Electroplating Society;
Society of Automotive Engineers.

Copies were also sent to the following foreign organizations through the American Engineering Standards Committee:

British Institute of Metals;
National Physical Laboratory;
British Engineering Standards Association;
French Commission Permanente de Standardization;

and also to the national standardizing bodies in each of the following countries:

Belgium
Canada
Germany
France
Great Britain
Holland
Sweden
Switzerland

The Secretary-Treasurer also requested the secretary of the American Engineering Standards Committee to keep him advised of any action that these organizations might take on the report.

Up to date we have received comments from the members of the Non-Ferrous Committee of the Society of Automotive Engineers and from the Normenauschuss der Deutschen Industrie. These comments have been favorable but are also somewhat non-committal and do not contain anything of a constructive nature. In addition to the above, there was considerable correspondence with the different members of the Non-Ferrous Committee of the S.A.E. and Mr. S. Tour, Metallurgist of the Technical Staff, Office of the Chief of Ordnance, Washington, D. C. relative to code numbering and classification schemes for non-ferrous alloys, proposed by Mr. Tour and Mr. R. W. Woodward of the Bureau of Standards, and the possibility of using this classification system in conjunction with the nomenclature of Sub-Committee IX.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 549 (1920).

It was the opinion of the chairman and other members of the Sub-Committee that it was not feasible to combine the two and that it would simply add confusion to any system of alloys.

Until all the comments and suggestions from the different Societies are available it is not deemed advisable to make any changes and therefore it is recommended that the sub-committee's report of progress contained in the report of Committee B-2 for 1920 remain open for another year until replies have been received from the different foreign and domestic societies.

SUB-COMMITTEE X ON METHODS OF TESTING.

During the past year this sub-committee has had no matters referred to it and therefore Mr. Merica, the chairman, simply reports progress. For new work the question of compression tests for non-ferrous alloys will be taken up.

All of the above reports of sub-committees were accepted by Committee B-2 and the recommendations in regard to the advancing of tentative standards to standard, etc., are approved and presented to the Society for action. The analysis of the letter ballot vote of the committee is as follows:

Items.	Affirmative.	Negative.	Not Voting.
TENTATIVE STANDARDS TO BE ADOPTED AS STANDARD.			
1. For Sheet High Brass (B 36 - 20 T)	25	0	27
2. For Bronze Bearing Metals for Turntables (B 22 - 18 T)	28	1	22
3. For Bronze Bearing Metals in Ingot Form (B 31 - 19 T)	31	1	24
4. For Solder Metal (B 32 - 19 T)	30	0	21
5. Methods for Chemical Analyses of Alloys of Lead, Tin, Antimony and Copper (B 18 - 20 T)	38	0	13
6. Light Aluminum Casting Alloys (B 26 - 19 T)	25	0	25
PROPOSED REVISIONS IN TENTATIVE STANDARDS.			
7. For Brass Ingot Metal for Sand Castings (B 30 - 19 T)	25	0	17
PROPOSED NEW TENTATIVE STANDARDS.			
8. For Nickel	27	0	23
9. Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys	26	0	25
10. Methods of Chemical Analysis of Nickel	23	0	28

This report has been submitted to letter ballot of the committee, which consists of 70 members, of whom 40 have voted affirmatively, 3 negatively, and 27 have refrained from voting.

Respectfully submitted on behalf of the committee,

WM. CAMPBELL,
Chairman.

P. D. MERICA,
Secretary.

ADDENDUM TO REPORT OF COMMITTEE B-2.

At a meeting of Committee B-2, held on Thursday, June 23, 1921, prior to the presentation of its annual report to the Society, additional revisions of tentative standards were recommended to be submitted to the Society in connection with the printed report of the committee.

TENTATIVE SPECIFICATIONS FOR NON-FERROUS ALLOYS FOR RAILWAY EQUIPMENT (B 17 – 18 T).[1]

Section 1 (b).—Before "Bearing Metal No. 1," insert the paragraph:

"*Phosphor Bronze*, for connecting-rod bearings, bushings, eccentric straps, crosshead gibs, and miscellaneous bushings, in place of Bearing Metal No. 1, when specifically covered in the contract."

Section 2 (a).—In the table on Chemical Composition, insert the following new requirements for Phosphor Bronze and revise the requirements for Bearing Metal No. 1 to read as indicated:

Alloy.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, max., per cent.	Iron, max., per cent.	Antimony, per cent.	Phosphorus, per cent.	Sulfur, max., per cent.	Arsenic max., per cent.	Total Impurities, including Zinc, max., per cent.
Phosphor Bronze....	remainder	9 – 11	8 – 11	**0.75**	0.25	0.25*a*	0.7 – 1.0	...	....	1.0
Bearing Metal No. 1..	remainder	9 – 11	9 – 11	**1.50**	0.25	0.25*a*	....	...	....	2.0

Delete Footnote *b* and insert a subscript letter "a" after the phosphorus requirement 0.02 for Bell Metal.

TENTATIVE METHODS FOR CHEMICAL ANALYSIS OF LEAD, TIN, ANTIMONY AND COPPER (B 18 – 20 T).[2]

1. *Part II, Rapid Methods for Control Work (a) Determination of Lead.*—Change to read as follows:

"In a covered 300-cc. Erlenmeyer flask dissolve 1 g. of the alloy in 20 cc. of H_2SO_4 (sp. gr. 1.84); heat the solution nearly to boiling until the metal is completely decomposed and the $PbSO_4$ is white (this may take ½ hour or more) and finally boil for several minutes. Allow to cool, but not below 60° C., and then add slowly 50 cc. of water while the solution is agitated. Heat to boiling for several minutes in order to insure complete solution of antimony sulfate. Allow the $PbSO_4$ to settle out until the solution is clear, not letting the temperature fall below 60° C. If the liquid does not clear quickly it must be heated longer. When clear pour the solution through a weighed porcelain Gooch crucible with asbestos mat, decanting the solution as completely as possible without allowing more than a very small amount of $PbSO_4$ to go over into the crucible. Now add 10 cc. more of H_2SO_4 (sp. gr. 1.84) to the $PbSO_4$ in the original flask, and boil for several minutes. Cool, add slowly 30 cc. of water, and again heat to boiling for a few minutes; allow the solution to cool to about 60° C. and completely transfer the $PbSO_4$ to the Gooch crucible. Wash with lead acid, retaining the filtrate and these washings for the copper determination. Remove the beaker containing these solutions and wash out the lead acid with dilute alcohol; set the Gooch crucible inside a porcelain crucible; dry and ignite for five minutes at the full heat of a Tirrill burner; cool and weigh as $PbSO_4$, which contains 68.29 per cent lead."

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 528 (1920).

[2] *Ibid.*, p. 589.

2. At the end of the Methods under (*c*) Determination of Tin, add the following paragraph to the Notes:

"For accurate work it is preferable to reduce and titrate the solution of tin in an atmosphere of CO_2."

Respectfully submitted,

WM. CAMPBELL,
Chairman.

P. D. MERICA,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Copper Bars for Locomotive Staybolts as presented in 1920 were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The specifications as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The Tentative Specifications for Sheet High Brass, for Bronze Bearing Metals for Turntables, for Bronze Bearing Metals in Ingot Form, for Solder Metal, and for Light Aluminum Casting Alloys referred to in this report were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards. The Tentative Methods for Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper amended as indicated in the report and in the Addendum were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Brass Ingot Metal for Sand Castings referred to in this report and the proposed revisions of the Tentative Specifications for Non-Ferrous Alloys for Railway Equipment as indicated in the Addendum were accepted. The specifications as thus revised appear on pages 486–494.

The proposed Tentative Specifications for Nickel and the proposed Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum Alloys and the proposed Tentative Methods of Chemical Analysis of Nickel were accepted for publication as tentative and appear on pages 495–526.

REPORT OF COMMITTEE C-2
ON
REINFORCED CONCRETE.

Ten of the twenty-two members of this committee are members of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete and have actively participated in its work. The Joint Committee has met five times and its sub-committees have held intermediate meetings. At its meeting April 13–15, 1921, Tentative Specifications for Concrete and Reinforced Concrete were agreed upon by the Joint Committee and have been included in its progress report which has been transmitted to the constituent organizations represented on the Committee.

The committee, in addition to its activities on the Joint Committee, has held two meetings and has in preparation Field Instructions covering the use of Concrete and Reinforced Concrete. The committee has felt, in view of the present situation, that it was not warranted in taking up actively the other lines of investigation until after the Joint Committee had reported tentative specifications so as to make more fully apparent lines of activity which would be helpful to, and at the same time not a duplication of the work of, the Joint Committee.

At the meeting of the committee held on November 10, 1920, the chairman reported the result of the Joint Conference in Philadelphia, September 29, 1920, between members of Sub-Committee V on Concrete Reinforcement Bars of Committee A-1 on Steel, of the Committee on Metal Reinforcement of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, of the Joint Committee on Culvert Pipe, of the Association of American Steel Manufacturers, and Committee C-2, for the purpose of reconciling differences between the Specifications for Concrete Reinforcement of the American Railway Engineering Association, of the American Society for Testing Materials, and the Association of American Steel Manufacturers concerning phosphorus, machining test specimens, and twisted bars.

The committee considered the position taken by Sub-Committee V of Committee A-1 in declining to omit the clause requiring the bar to be machined for testing, for the reason that the Society's specifications should govern the quality of the metal used and not the design, which is an engineering problem and, therefore, not in the province of the Society, and adopted the following motions, Mr. E. E. Hughes voting in the negative on motions (1), (2) and (3):

"1. That it is the sense of this committee that metal reinforcement shall be tested in the form in which it is delivered for use in the structure.

"2. That this committee does not approve of the provision of the American Society for Testing Materials' specification which provides that metal reinforcement may be machined before testing.

"3. That it is the sense of this committee that there should not be two standards in the Society, one for the quality of the metal used and another for the bars rolled therefrom, but there should be a single standard specification for metal reinforcement in which the reinforcement shall be tested as rolled.

"4. That this committee endorses the recommendation of Sub-Committee V of Committee A-1, which is as follows:

> "*Whereas*, Reliable information in regard to the physical properties of plain, deformed, and twisted bars of the different grades of steel, is undoubtedly required by engineers and manufacturers; therefore, be it
>
> "*Resolved*, That this sub-committee recommend to Committee A-1 that the American Society for Testing Materials appoint a proper committee whose duty it shall be to thoroughly investigate the whole subject of physical properties in steel reinforcement bars, plain, deformed and twisted, and rolled from the four different grades now in commercial use, in the form as rolled and in machined test specimens;

"And that the Executive Committee of the Society be asked to appoint a General Committee of A-1 and C-2 to carry out the investigation recommended."

The Executive Committee of the Society at its meeting on April 11, 1921, suggested that Committee A-1 on Steel prepare a specification for concrete reinforcement bars as used, and approved the joint recommendation of the Committee on Steel and the Committee on Reinforced Concrete that a proper committee be appointed to investigate the subject of physical properties of concrete reinforcement bars. Arrangements are now being made for an organization meeting of this committee.

The committee reports the resignation of Henry C. Turner, President, Turner Construction Co., and of A. L. Johnson, President, Corrugated Bar Co., and the election of A. W. Stephens and W. S. Thompson, respectively Chief Engineers of the same companies.

The committee asks that it be continued.

This report has been submitted to letter ballot of the committee which consists of 22 members, of whom 20 have voted affirmatively, none negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the committee,

RICHARD L. HUMPHREY,
Chairman.

S. C. HOLLISTER,
Secretary.

PROGRESS REPORT
OF THE
JOINT COMMITTEE ON STANDARD SPECIFICATIONS
FOR
CONCRETE AND REINFORCED CONCRETE

SUBMITTING
TENTATIVE SPECIFICATIONS FOR CONCRETE AND REINFORCED CONCRETE

Affiliated Committees
OF THE
American Society of Civil Engineers
American Society for Testing Materials
American Railway Engineering Association
American Concrete Institute
Portland Cement Association

Submitted to Constituent Organizations
June 4, 1921

PREFACE.

The Joint Committee on Standard Specifications for Concrete and Reinforced Concrete consists of five representatives from each of the following:

American Society of Civil Engineers,
American Society for Testing Materials,
American Railway Engineering Association,
American Concrete Institute,
Portland Cement Association.

This Committee is the successor of the Joint Committee on Concrete and Reinforced Concrete which was organized in Atlantic City, N. J., June 17, 1904, and was formed by the union of special committees appointed in 1903 and 1904 by the above-named organizations, except the American Concrete Institute which was added by invitation of the Joint Committee in 1915. The previous Committee presented progress reports in 1909 and 1912 and adopted a final report to its constituent organizations on July 1, 1916. It was the purpose of that Committee to prepare a Recommended Practice for Concrete and Reinforced Concrete. Its final report stated:

"The report is not a specification but may be used as a basis for specifications."

The present Joint Committee is charged with the preparation of Specifications for Concrete and Reinforced Concrete and in preparing these specifications is using as a basis the report of the former Joint Committee with such modifications as are necessary to make its recommendations agree with current practice, and such new data as mark advances in the art.

The initiative in bringing about the present Joint Committee was taken by the Committee on Reinforced Concrete of the American Society for Testing Materials on June 27, 1917, when the committee voted to request the Executive Committee of the Society to invite the Member-Societies of the previous Joint Committee to cooperate in the formation of a new Joint Committee. The Executive Committee approved this request on April 25, 1919, and an invitation was issued to each of the above-named organizations by the Executive Committee on behalf of the American Society for Testing

Materials, to appoint five members on a Joint Committee on Specifications for Reinforced Concrete. The last of these organizations accepted the invitation on November 22, 1919. On January 21, 1920, a call for an organizing meeting on February 11, 1920, was sent by the Executive Committee of that Society to each of the twenty-five representatives of cooperating organizations, together with a list of members of the Joint Committee, and an outline of organization that had been previously submitted by the American Society for Testing Materials to and approved by the cooperating organizations.

The organizing meeting was held at the Engineers' Club, Philadelphia, Pa., and was called to order by George S. Webster, then Vice-President of the American Society for Testing Materials, who explained tat he had been directed by the Executive Committee of that Society to act as Temporary Chairman; he further stated that C. L. Warwick, Secretary-Treasurer of the Society, had been requested to act as Temporary Secretary until a formal organization of the Joint Committee had been effected.

The personnel of the Joint Committee is as follows:

American Society of Civil Engineers.

Rudolph P. Miller, *Chairman*,
Consulting Engineer, New York City.
Resigned March 28, 1921. Succeeded as Chairman by
W. A. Slater, Engineer-Physicist,
Bureau of Standards, Washington, D. C.
William K. Hatt, Professor of Civil Engineering,
Purdue University, Lafayette, Ind.
A. E. Lindau, General Manager of Sales,
Corrugated Bar Company, Buffalo, N. Y.
Sanford E. Thompson, Consulting Engineer,
Boston, Mass.
Appointed to fill vacancy,
Franklin R. McMillan,
628 Metropolitan Bank Building, Minneapolis, Minn.

American Society for Testing Materials.

Richard L. Humphrey, *Chairman*,
Consulting Engineer, Philadelphia, Pa.
Albert T. Goldbeck, Engineer of Tests,
Bureau of Public Roads, Washington, D. C.
Edward E. Hughes, Vice-President,
Franklin Steel Works, Franklin, Pa.
Henry H. Quimby, Chief Engineer,
Department of City Transit, Philadelphia, Pa.
Leon S. Moisseiff, Consulting Engineer,
New York City.

American Railway Engineering Association.

J. J. Yates, ***Chairman***,
Bridge Engineer, Central Railroad of New Jersey, Jersey City, N. J.
George E. Boyd, Division Engineer,
Delaware, Lackawanna and Western Railroad Company, Buffalo, N. Y.
Frederick E. Schall, Bridge Engineer,
Lehigh Valley Railroad Company, Bethlehem, Pa.
H. T. Welty, Engineer of Structures,
New York Central Railroad, New York City.
C. C. Westfall, Engineer of Bridges,
Illinois Central Railroad Company, Chicago, Ill.

American Concrete Institute.

S. C. Hollister, ***Chairman***,
Consulting Engineer, Philadelphia, Pa.
Robert W. Lesley, Past-President, Association of American Portland Cement Manufacturers,
Philadelphia, Pa.
Arthur R. Lord, President,
Lord Engineering Company, Chicago, Ill.
Egbert J. Moore, Vice-President,
Turner Construction Company, New York City.
Leonard C. Wason, President,
Aberthaw Construction Company, Boston, Mass.
Resigned October 19, 1920. Succeeded by
Angus B. MacMillan, Chief Engineer,
Aberthaw Construction Company, Boston, Mass.

Portland Cement Association.

Frederick W. Kelley, ***Chairman***,
President, Helderberg Cement Company, Albany, N. Y.
Duff A. Abrams, Professor in Charge,
Structural Materials Research Laboratory, Lewis Institute, Chicago, Ill.
Ernest Ashton, Chemical Engineer,
Lehigh Portland Cement Company, Allentown, Pa.
Edward D. Boyer, Cement Expert,
Atlas Portland Cement Company, New York City.
J. H. Libberton, Manager Service Bureau,
Universal Portland Cement Company, Chicago, Ill.
Resigned January 1, 1921. Succeeded by
J. E. Freeman, Manager, Structural Bureau,
Portland Cement Association, Chicago, Ill.

The Committee perfected a permanent organization on February 11, 1920, under the title "Joint Committee on Standard Specifications for Concrete and Reinforced Concrete" with the following officers:

Chairman, Richard L. Humphrey, Philadelphia, Pa.,
Vice-Chairman, J. J. Yates, Jersey City, N. J.,
Secretary-Treasurer, Duff A. Abrams, Chicago, Ill.,

and an Executive Committee consisting of these officers, and Rudolph P. Miller,[1] New York City, and S. C. Hollister, Philadelphia.

The Committee adopted Rules of Organization and apportioned the work of preparing a tentative draft of the specifications among sub-committees, the present personnel of which is given below:

1. *Materials (other than Reinforcing).*
Albert T. Goldbeck, *Chairman*
Duff A. Abrams
J. E. Freeman[2]
Sanford E. Thompson
J. J. Yates

2. *Metal Reinforcement.*
J. J. Yates, *Chairman*
Duff A. Abrams
William K. Hatt
Edward E. Hughes
A. E. Lindau

3. *Proportioning and Mixing.*
W. A. Slater, *Chairman*
Duff A. Abrams
Ernest Ashton
George E. Boyd
Henry H. Quimby

4. *Forms and Placing.*
George E. Boyd, *Chairman*
Edward D. Boyer
Angus B. MacMillan[3]
Egbert J. Moore
Frederick E. Schall

5. *Design.*
S. C. Hollister, *Chairman*
William K. Hatt
A. E. Lindau
Arthur R. Lord
Franklin R. McMillan
Egbert J. Moore
W. A. Slater
H. T. Welty

6. *Details of Construction and Fireproofing.*
Franklin R. McMillan,[4] *Chairman*
William K. Hatt
Arthur R. Lord
Leon S. Moisseiff
C. C. Westfall

7. *Waterproofing and Protective Treatment.*
Frederick W. Kelley, *Chairman*
Albert T. Goldbeck
S. C. Hollister
Robert W. Lesley
C. C. Westfall

8. *Surface Finish.*
Henry H. Quimby, *Chairman*
Edward D. Boyer
J. E. Freeman[2]
Angus B. MacMillan[3]
H. T. Welty

9. *Form of Specification.*
Richard L. Humphrey, *Chairman*
Duff A. Abrams, *Secretary*
George E. Boyd
Albert T. Goldbeck
S. C. Hollister
Frederick W. Kelley
Franklin R. McMillan[4]
Henry H. Quimby
W. A. Slater
J. J. Yates

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[1] Succeeded by W. A. Slater, May 25, 1921.

[2] Succeeded J. H. Libberton, January 1, 1921.

[3] Succeeded Leonard C. Wason, October 19, 1920.

[4] Succeeded Rudolph P. Miller, May 25, 1921.

The Joint Committee held the following meetings:

Organization meeting, Philadelphia, February 11, 1920.
Second meeting, Asbury Park, N. J., June 23 and 24, 1920.
Third meeting, New York City, October 26, 27 and 28, 1920.
Fourth meeting, New York City, December 15, 16 and 17, 1920.
Fifth meeting, New York City, March 2, 3 and 4, 1921.
Sixth meeting, New York City, April 13, 14 and 15, 1921.

At these meetings the Committee considered the reports of its sub-committees which were edited by the Sub-Committee on Form and incorporated in the Tentative Specifications for Concrete and Reinforced Concrete herewith submitted.

The Rules of Organization of the Joint Committee which were submitted to, and approved by, each of its constituent organizations, provide that,

> "The initial report of the Joint Committee shall be considered by each of the five organizations as a tentative report submitted for criticism and discussion limited to not less than six months nor more than one year. Such discussions shall then be referred to the Joint Committee for consideration in revising its report." (Article IX, Section 2.)

The Joint Committee, in submitting these Tentative Specifications for Concrete and Reinforced Concrete in accordance with the above requirement, wishes it clearly understood that it reserves the right to make such changes as may be found desirable, after a further study of the available data. While not prepared to submit a final report at this time the Committee is of the opinion that the specifications are in such shape as to make it desirable to issue them tentatively for the purpose of facilitating the final submission of Standard Specifications for Concrete and Reinforced Concrete.

The Joint Committee earnestly requests that every facility be provided by its constituent organizations for the fullest consideration of these Tentative Specifications in order that it may be in a position, as a result of their thorough discussion, to reflect in the final specifications the best current practice.

The Joint Committee further calls attention to the fact that it has undertaken to prepare specifications covering the fundamentals to be observed in the general use of concrete and reinforced concrete; no attempt has been made to cover the details involved in the use of these materials in special structures. While the sections relating to design deal primarily with building construction, nevertheless the principles involved are in general applicable to structures of other types. It is expected that in using these specifications the necessary supplemental requirements will be added covering details.

This report has been submitted to letter ballot of the committee which consists of 25 members, representing five societies, all of whom have voted affirmatively.

Respectfully submitted,

Richard L. Humphrey, *Chairman.*
J. J. Yates, *Vice-Chairman.* Duff A. Abrams, *Secretary-Treasurer.*

Ernest Ashton,
George E. Boyd,
Edward D. Boyer,
J. E. Freeman,
Albert T. Goldbeck,
William K. Hatt,
S. C. Hollister,
Edward E. Hughes,
Frederick W. Kelley,
Robert W. Lesley,
A. E. Lindau,
Arthur R. Lord,
Angus B. Mac Millan,
Franklin R. McMillan,
Leon S. Moisseiff,
Egbert J. Moore,
Henry H. Quimby,
Frederick E. Schall,
W. A. Slater,
Sanford E. Thompson,
H. T. Welty,
C. C. Westfall.

TABLE OF CONTENTS.

Section. Page.

I. General Instructions 1 221
II. Definitions 2 221–224
III. Quality of Concrete 3–5 225

IV. Materials

A. Portland Cement 6 225
B. Fine Aggregate 7–12 225–226
C. Coarse Aggregate 13–15 226–227
D. Rubble and Cyclopean Aggregate 16–17 227
E. Storage of Aggregate 18 227
F. Water 19 227
G. Metal Reinforcement 20–25 227–228

V. Proportioning and Mixing Concrete

A. Proportioning 26–28 229–230
B. Consistency 29 230
C. Mixing 30–33 231

VI. Depositing Concrete

A. Depositing in Air 34–43 231–233
B. Rubble and Cyclopean Concrete 44–45 233
C. Depositing under Water 46–51 233–234
VII. Forms 52–58 234–235

VIII. Details of Construction

A. Metal Reinforcement 59–65 235–236
B. Concrete Covering over Metal 66–68 236–237
C. Joints 69–77 237–238

IX. Waterproofing and Protective Treatment

A. Waterproofing 78–81 238
B. Oilproofing 82 239
C. Concrete in Sea Water 83–86 239
D. Concrete in Alkali Soils or Water 87–91 239–240
X. Surface Finish 92–104 240–242

XI. Design

A. General Assumptions 105 242–243
B. Flexure of Rectangular Reinforced Concrete Beams and Slabs 106–111 243–247
C. Flexure of Reinforced Concrete T-Beams 112–119 247–249

D. Diagonal Tension and Shear

a. Formulas and Notation 120–121 249–250
b. Beams without Web Reinforcement 122–123 250
c. Beams with Web Reinforcement 124–135 250–253
d. Flat Slabs 136 253–254
e. Footings 137–139 254
E. Bond 140–144 254–255
F. Flat Slabs 145–162 255–260
G. Reinforced Concrete Columns 163–173 260–263
H. Footings 174–191 263–266

		SECTION.	PAGE.
I.	Retaining Walls	192–195	267–268
J.	Floor Slabs Supported on Four Sides	......	268
K.	Shrinkage and Temperature Stresses	......	268
L.	Summary of Working Stresses	196–208	268–269

LIST OF TABLES.

I.	Size and Areas of Reinforcement Bars	22	228
II.	Workability of Concrete	29	230
III.	Moments to be Used in Design of Flat Slabs	147	256
IV.	Proportions for Concrete of Given Compressive Strength at 28 Days	...	270–274

LIST OF APPENDICES.

The specifications and methods of test given in Appendices 3 to 15, inclusive, form a part of the Tentative Specifications for Concrete and Reinforced Concrete.[1]

		PAGE.
1.	Standard Notation	275–277
2.	Figures	278–283
3.	Standard Specifications and Tests for Portland Cement (C 9 – 21)[2]	.....
4.	Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 14)[2]	.....
5.	Standard Specifications for Rail-Steel Concrete Reinforcement Bars (A 16 – 14)[2]	.....
6.	Standard Specifications for Structural Steel for Bridges (A 7 – 21)[2]	.....
7.	Standard Specifications for Structural Steel for Buildings (A 9 – 21)[2]	.....
8.	Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (A 82 – 21 T)[3]	.....
9.	Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 – 21 T)[3]	.....
10.	Standard Method of Test for Quantity of Clay and Silt in Sand for Highway Construction (D 74 – 21)[2]	.....
11.	Tentative Method of Test for Organic Impurities in Sands for Concrete (C 40 – 21 T).[3]	.....
12.	Tentative Specifications for Workability of Concrete for Concrete Pavements (D 62 – 20 T)[4]	.....
13.	Tentative Methods of Making Compression Tests of Concrete (C 39 – 21 T)[3]	.....
14.	Standard Methods of Making and Storing Specimens of Concrete in the Field (C 31 – 21)[2]	.....
15.	Standard Specifications for Cast-Iron Pipe and Special Castings (A 44 – 04)[2]	.....

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[1] These specifications and methods of test are those of the American Society for Testing Materials, either in their present form as adopted by the Society or in the form in which the respective committees of the Society will recommend them for action at the annual meeting of the Society, June 21-24, 1921.

[2] **American Society for Testing Materials, 1921 Book of A. S. T. M. Standards.**

[3] See pp. 5–6 for location of these tentative standards.—ED.

[4] American Society for Testing Materials, *Proceedings*, Vol. XX, Part 1 (1920).

TENTATIVE SPECIFICATIONS
FOR
CONCRETE AND REINFORCED CONCRETE.

I. GENERAL INSTRUCTIONS.

General Instructions.

1. These specifications are not complete; they cover the general conditions affecting the use of concrete and reinforced concrete. To complete them it will be necessary for the engineer to

(*a*) Provide the detail specifications covering the work in particular in which the concrete and reinforced concrete are to be used;

(*b*) Insert in Section 4 the strengths required for the several classes of concrete specified, based either upon preliminary tests or upon the values given in Table IV;

(*c*) Insert in Section 14 the sizes of aggregates required;

(*d*) Strike out one of the titles of the specifications in Section 20;

(*e*) Strike out one of the titles of the specifications in Section 24;

(*f*) Strike out one of the words "volume" or "weight" in Section 27;

(*g*) Strike out two of the three Sections 28 and fill in the necessary blanks for the proportions;

(*h*) Insert in Section 29 the slumps required;

(*i*) Strike out the method or methods inapplicable to the work, in Section 50;

(*j*) Strike out one of the two Sections 97.

II. DEFINITIONS.

Definitions.

2. The following definitions give the meaning of certain terms as used in these specifications:

Acid Proofing.—Treatment of a concrete surface to resist the action of acid solutions.

Aggregate.—Inert material which is mixed with Portland cement and water to produce concrete; in general aggregate consists of sand, pebbles, gravel, crushed stone or gravel, or similar materials. (See *Fine Aggregate, Coarse Aggregate.*)

Approved.—Meeting the approval of, or specifically authorized by, the Engineer.

Buttressed Retaining Wall.—A reinforced concrete wall having a vertical stem and a horizontal base, with brackets on the side opposite the pressure face uniting the vertical section with the toe of the base.

Cantilever Retaining Wall.—A reinforced concrete wall having a vertical stem and a horizontal base, each of which resists by cantilever action the pressure to which it is subjected.

Cellular Retaining Wall.—A reinforced concrete wall with a horizontal base, longitudinal vertical sections, and a series of transverse walls, dividing the space between the longitudinal walls into cells which are filled with earth, or other suitable material. If the top of the cells is covered by a floor slab, the front longitudinal wall and the filling may be omitted.

Coarse Aggregate.—Aggregate retained on a No. 4 sieve and of a maximum size generally not larger than 3 in. (See *Aggregate, Fine Aggregate.*)

Column.—A vertical compression member whose length exceeds three times its least horizontal dimension.

Column Capital.—An enlargement of the upper end of a reinforced concrete column built monolithic with the column and flat slab to increase the moment of inertia of the column and the shearing resistance of the slab at sections where high bending moment or high shear may occur.

Column Strip.—A portion of a panel of a flat slab which has a uniform width equal to one-fourth of the panel length on a line perpendicular to the direction of the strip, and whose outer edge lies on the edge of the panel. (See *Middle Strip.*)

Concrete.—A mixture of Portland cement, fine aggregate, coarse aggregate and water. (See *Mortar.*)

Consistency.—A general term used to designate the relative plasticity of freshly mixed mortar and concrete.

Counterforted Retaining Wall.—A reinforced concrete wall having a vertical stem and a horizontal base with brackets on the pressure face uniting the vertical section with the heel of the base.

Crusher-Run Stone.—Unscreened crushed stone. (See *Stone Screenings.*

Cyclopean Concrete.—Concrete in which stones larger than one-man size are individually embedded.

Dead Load.—The weight of the structure plus fixed loads and forces.

Deformed Bar.—Reinforcement bar with shoulders, lugs or projections formed integrally from the body of the bar during rolling.

Diagonal Direction.—A direction parallel or approximately parallel to the diagonal of the panel.

Dropped Panel.—The structural portion of a flat slab which is thickened throughout an area surrounding the column capital.

Effective Area of Concrete.—The area of a section of the concrete which lies between the tension reinforcement and the compression surface of the beam or slab.

Effective Area of Reinforcement.—The area obtained by multiplying the right cross-sectional area of the metal reinforcement by the cosine of the angle between the direction of the reinforcement bars or wires, and the direction for which the effectiveness of the reinforcement is to be determined.

Engineer.—The engineer in responsible charge of design and construction.

Fine Aggregate.—Aggregate passing through a No. 4 sieve. (See *Aggregate, Coarse Aggregate.*)

Flat Slab.—A flat concrete floor or roof plate having reinforcement bars extending in two or more directions and having no beams or girders to carry the load to the supporting columns.

Footing.—A structural unit used to distribute wall or column loads to the supporting material, either directly or through piles.

Gravel.—Loose material containing particles larger than sand, resulting from natural crushing and erosion of rocks. (See *Sand.*)

Laitance.—The extremely fine particles which separate from freshly deposited mortar or concrete and collect on the top surface.

Live Load.—Loads and forces which are variable.

Membrane Waterproofing.—A coating reinforced by fabric, felt, or similar toughening material applied to structures to prevent contact of moisture.

Middle Strip.—The portion of a panel of a flat slab which extends in a direction parallel to a side of the panel, whose width is one-half the panel length on a line at right angles to the direction of the strip and whose center line lies on the center line of the panel. (See *Column Strip.*)

Mortar.—A mixture of Portland cement, fine aggregate and water. (See *Concrete.*)

Negative Reinforcement.—Reinforcement so placed as to take stress due to negative bending moment.

Oilproofing.—Treatment of a concrete surface to resist the action of mineral, animal, or vegetable oils.

One-Man Stone.—Stone larger than coarse aggregate and not exceeding 100 lb. in weight. (See *Rubble Concrete.*)

Panel Length.—The distance between centers of two columns of a panel, in either rectangular direction.

Pedestal or Pier.—A vertical compression member whose length does not exceed three times its least horizontal dimension.

Pedestal Footing.—A member supporting a column, in which the projection from the face of the column on all sides is less than one-half the depth.

Plain Concrete.—Concrete without metal reinforcement.

Positive Reinforcement.—Reinforcement so placed as to take stress due to positive bending moment.

Portland Cement.—The product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

Principal Design Section.—The vertical sections in a flat slab on which the moments in the rectangular directions are critical. (See Section 146.)

Ratio of Reinforcement.—The ratio of the effective area of the reinforcement cut by a section of a beam or slab to the effective area of the concrete cut by that section.

Rectangular Direction.—A direction parallel to a side of the panel.

Reinforced Concrete.—Concrete in which metal is embedded in such a manner that the two materials act together in resisting stress.

Rubble Aggregate.—Stone or gravel larger than coarse aggregate and not larger than one-man stone (See *One-Man Stone.*)

Rubble Concrete.—Concrete in which pieces of rubble aggregate are individually embedded. (See *Rubble Aggregate.*)

Sand.—Loose material consisting of small grains (commonly quartz) resulting from the natural disintegration of rocks. (See *Gravel.*)

Screen.—A metal plate with closely spaced circular perforations. (See *Sieve.*)

Sieve.—Woven wire cloth with square openings. (See *Screen.*)

Slump.—The shortening of a standard test mass of concrete used as a measure of workability.

Standard Sand.—Natural sand mined at Ottawa, Ill., screened to pass a No. 20 sieve and retained on a No. 30 sieve, used as the fine aggregate in standard strength tests of Portland cement. (See Appendix 3 for Specifications.)

Stone Screenings.—Unscreened crushed stone passing through a No. 4 sieve. (See *Crusher-Run Stone.*)

Tremie.—A water-tight pipe of suitable dimensions, generally used in a vertical position, for depositing concrete under water.

Wall Beam.—A reinforced concrete beam which extends from column to column along the outer edge of a wall panel.

III. QUALITY OF CONCRETE.

Quality.

3. The quality of concrete shall be expressed in terms of workability as determined by the slump test and of the compressive strength at 28 days as determined by concrete tests of the materials to be used as specified in Section 28. The proportions required to produce concrete having the strength specified in Section 4 shall be determined in advance of the mixing of the concrete.

Strength.

4. The concrete shall develop under the conditions specified in Section 3, for the various parts of the work, the following strengths[1]:

.... lb. per sq. in.

.... lb. per sq. in.

.... lb. per sq. in.

.... lb. per sq. in.

Tests of Field Specimens.

5. Field concrete test specimens shall be made, stored and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Serial Designation: C 31-21) of the American Society for Testing Materials. (Appendix 14.)

IV. MATERIALS.

A. Portland Cement.

Portland Cement.

6. Portland cement shall conform to the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9-21) of the American Society for Testing Materials[2] (Appendix 3) and subsequent revisions thereof.

B. Fine Aggregate.

General Requirements.

7. Fine aggregate shall consist of sand, stone screenings or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances.

Grading.

8. Fine aggregate shall range in size from fine to coarse, preferably within the following limits:

Passing through No. 4 sieve.............not less than 95 per cent

Passing through No. 50 sieve.............not more than 30 "

Weight removed by decantation .... " " " 3 "

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[1] The engineer should insert the strengths required for the several classes of concrete specified, based either upon preliminary tests or upon the values given in Table IV.

[2] These specifications are also a standard of the following organizations: American Engineering Standards Committee, United States Government, American Railway Engineering Association, American Concrete Institute, and the Portland Cement Association.

Sieve Analysis.

9. The sieves and method of making sieve analysis shall conform to the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41–21 T) of the American Society for Testing Materials. (Appendix 9.)

Decantation Test.

10. The decantation test shall be made in accordance with the Standard Method of Test for Quantity of Clay and Silt in Sand for Highway Construction (Serial Designation: D 74–21) of the American Society for Testing Materials. (Appendix 10.)

Mortar Strength Test.

11. Fine aggregate shall preferably be of such a quality that mortar briquettes, cylinders or prisms, consisting of one part by weight of Portland cement and three parts by weight of fine aggregate,[1] mixed and tested in accordance with the methods described in the Standard Specifications and Tests for Portland Cement (Appendix 3) will show a tensile or compressive strength at ages of 7 and 28 days not less than that of 1 : 3 standard Ottawa sand mortar of the same plasticity made with the same cement. However, fine aggregate which fails to meet this requirement may be used, provided the proportions of cement, fine aggregate, coarse aggregate and water are such as to produce concrete of the strength specified.[2] Concrete tests shall be made in accordance with the Tentative Methods of Making Compression Tests of Concrete (Serial Designation: C 39–21 T) of the American Society for Testing Materials. (Appendix 13.)

Organic Impurities in Sand.

12. Natural sand which shows a color darker than the standard color when tested in accordance with the Tentative Method of Test for Organic Impurities in Sands for Concrete (Serial Designation: C 40–21 T) of the American Society for Testing Materials (Appendix 11) shall not be used, unless the concrete made with the materials and in the proportions to be used on the work is shown by tests to be of the required strength.

C. *Coarse Aggregate.*

General Requirements.

13. Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

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[1] In testing aggregate, care should be exercised to avoid the removal of any coating on the grains which may affect the strength. Natural sand should not be dried before being made into mortar, but should contain natural moisture. The quantity of water contained may be determined on a separate sample and the weight of the sand used in the test corrected for the moisture content.

[2] Table IV furnishes a guide in determining the proportions of materials required to produce a concrete of a given strength, using aggregates of various sizes and concrete of different consistencies.

Grading. 14. Coarse aggregate shall range in size from fine to coarse within the following limits[1]:

Passing —[a] in. Sieve (maximum size).......not more than 95 per cent
Passing —[a] in. " (intermediate size).... —[a] to —[a] "
Passing No. 4 " ....not more than 15 "
Passing No. 8 " .... " " " 5 "

Sieve Sizes. 15. The test for size and grading of aggregate shall be made in accordance with the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete. (Appendix 9.)

D. *Rubble and Cyclopean Aggregate.*

Rubble Aggregate. 16. Rubble aggregate shall consist of clean, hard, durable stone larger than coarse aggregate and not larger than one-man stone.

Cyclopean Aggregate. 17. Cyclopean aggregate shall consist of clean, hard, durable stone, free from fissures and planes of cleavage and larger than one-man stone.

E. *Storage of Aggregate.*

Aggregate Storage. 18. Aggregate shall be so stored on platforms or otherwise as to avoid the inclusion of foreign materials. Before using, frost, ice and lumps of frozen materials shall be removed.

F. *Water.*

General Requirements. 19. Water for concrete shall be clean and free from oil, acid, alkali, organic matter, or other deleterious substance.

G. *Metal Reinforcement.*

Quality. 20. Metal reinforcement shall be of a quality and character meeting the requirements of the Standard Specifications[2] for Billet-Steel Concrete Reinforcement Bars (Serial Designation: A 15–14) of the American Society for Testing Materials (Appendix 4), Standard

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[1] Where several suitable aggregates are available, a thorough investigation of the relative economy of each for producing concrete of the desired strength is advisable, especially for work of considerable magnitude.

[a] The engineer should insert in these blanks the sizes of aggregates required. The size and grading to be used will be governed by local conditions. The limitation on size and grading is intended to secure uniformity of aggregate. The following table indicates desirable gradings for coarse aggregate for certain maximum sizes:

Maximum Size of Aggregate, in.	Per Cent by Weight Passing Through Standard Sieves with Square Openings.					Per Cent Passing, not more than	
	3 in.	2 in.	1½ in.	1 in.	¾ in.	No. 4 Sieve.	No. 8 Sieve.
3............	100	...	40 – 75	...	...	15	5
2............	...	100	...	40 – 75	...	15	5
1½............	...	...	100	...	40 – 75	15	5
1............	...	...	...	100	...	15	5
¾............	...	...	...	...	100	15	5

[2] See footnote 1, p. 228.

Specifications[1] for Rail-Steel Concrete Reinforcement Bars (Serial Designation: A 16–14) of the American Society for Testing Materials (Appendix 5), except that the provision for machining deformed bars before testing shall be eliminated.

Wire. 21. Wire for concrete reinforcement shall conform to the requirements of the Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (Serial Designation: A 82–21 T) of the American Society for Testing Materials. (Appendix 8.)

Standard Sizes of Bars. 22. Reinforcement bars shall conform to the areas and equivalent sizes shown in Table I.

TABLE I.—SIZES AND AREAS OF REINFORCEMENT BARS.

Size of Bar, in.	Area, sq. in.	
	Round	Square.
$\frac{3}{8}$	0.110	.....
$\frac{1}{2}$	0.196	0.250
$\frac{5}{8}$	0.307	.....
$\frac{3}{4}$	0.442	.....
$\frac{7}{8}$	0.601	.....
1	0.785	1.000
$1\frac{1}{8}$	.....	1.266
$1\frac{1}{4}$	.....	1.563

The areas of deformed bars shall be determined by the minimum cross-section thereof.

Deformed Bars. 23. An approved deformed bar shall be one that will develop a bond strength at least 25 per cent greater than that of a plain round bar of equivalent cross-sectional area.[2]

Structural Shapes. 24. Structural steel shapes used for reinforcement shall conform to the requirements of the Standard Specifications[3] for Structural Steel for Bridges (Serial Designation: A 7–21) of the American Society for Testing Materials (Appendix 6), Standard Specifications[3] for Structural Steel for Buildings (Serial Designation: A 9–21) of the American Society for Testing Materials. (Appendix 7.)

Cast Iron. 25. The quality of cast iron used in composite columns shall conform to the requirements of the Standard Specifications for Cast-Iron Pipe and Special Castings (Serial Designation: A 44–04) of the American Society for Testing Materials. (Appendix 15.)

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[1] The engineer should strike out one of these titles. The Committee recommends as preferred material for reinforcement that meeting the requirements of the Standard Specifications for Billet-Steel Concrete Reinforcement Bars of intermediate grade (except as noted under Section 20), made by the open-hearth process.

[2] The Committee has under consideration a specification for deformed bars but is not prepared at this time to make more definite recommendations.

[3] The engineer should strike out one of these titles.

V. PROPORTIONING AND MIXING CONCRETE.

A. Proportioning.

Unit of Measure. 26. The unit of measure shall be the cubic foot. Ninety-four pounds (one bag or $\frac{1}{4}$ bbl.) of Portland cement shall be considered as one cubic foot.

Method of Measuring. 27. Each of the constituent materials shall be measured separately by volume[1] weight.[1] The method of measurement shall be such as to secure the specified proportions in each batch. If volume measurement is used, the fine aggregate and the coarse aggregate shall be measured loose as thrown into the measuring device. The water shall be measured by an automatic device that will insure the same quantity in successive batches.

Proportions. 28.[2] The proportions of cement, water and aggregate shall be such as to produce concrete of the strength and quality specified in Sections 3 and 4. The proportions shall be 1 part of Portland cement, —[a] parts of fine aggregate, and —[a] parts of coarse aggregate as determined by the engineer from concrete tests of the materials to be used. The tests shall be made in accordance with the Tentative Methods of Making Compression Tests of Concrete. (Appendix 13.) The quantity of water used shall be such as to produce concrete of the consistency required by the particular class of work and shall be as specified in Section 29. In case the grading of the supply of available aggregate varies from that upon which the proportions were based, such aggregate may be used, provided the new proportions, as determined by the engineer, are such as to produce concrete of the required strength and quality.

Proportions. 28.[2] The contractor shall use materials, so proportioned and mixed, as to produce concrete of the required workability and strength.[3] Frequent compression tests of the concrete used in the work will be made by the engineer, and in case of failure to meet the specified strength, the contractor shall make such changes in the materials, proportions, or mixing, as may be necessary to secure concrete of the required strength. Concrete tests shall be made in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Appendix 14) and the Tentative Methods of Making Compression Tests of Concrete (Appendix 13).

Proportions. 28.[2] The proportions shall be 1 part of Portland cement, —[a] parts of fine aggregate, and —[a] parts of coarse aggregate. The proportions of materials shall be selected from Table IV. In case the grading of the supply of available aggregate varies from that upon which the proportions were based, such aggregate may be used, provided the new proportions, as determined by the engineer, are such as to produce concrete of the required strength and quality.

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[1] The engineer should strike out one of these terms.

[2] The engineer should indicate his choice of the method of proportioning to be used by striking out two of the Sections numbered 28.

[3] The use of this method should be accompanied by a clause in the contract which indicates the procedure to be followed in case tests show that concrete of the specified strength has not been obtained.

[a] The engineer should fill in these blanks.

B. Consistency.

Consistency. 29. The engineer shall determine and specify the consistency of the concrete for various portions of the work based on tests of the materials to be used. The consistency of the concrete shall be measured by the slump test in the manner described in the Tentative Specifications for Workability of Concrete for Concrete Pavements (Serial Designation: D 62-20 T) of the American Society for Testing Materials. (Appendix 12.) The slump for different types of concrete shall not be greater than indicated in Table II.

TABLE II.—WORKABILITY OF CONCRETE.

Type of Concrete.	Maximum Slump, in.
1. Mass concrete	[a]
2. Reinforced concrete:	
(*a*) Thin vertical sections and columns	[a]
(*b*) Heavy sections	[a]
(*c*) Thin confined horizontal sections	[a]
3. Roads and pavements:	
(*a*) Hand finished	[a]
(*b*) Machine finished	[a]
4. Mortar for floor finish	[a]

The consistency shall be checked from time to time during the progress of the work.

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[a] The engineer should insert the slumps required, based on tests called for in this section. The slump test requirement is intended to insure concrete mixed with the minimum quantity of water required to produce a plastic mixture. The following table indicates the maximum slump desirable for the various types of concrete, based on average aggregates and proportions:

Type of Concrete.	Maximum Slump, in.
1. Mass concrete	2
2. Reinforced concrete:	
(*a*) Thin vertical sections and columns	6
(*b*) Heavy sections	2
(*c*) Thin confined horizontal sections	8
3. Roads and pavements:	
(*a*) Hand finished	4
(*b*) Machine finished	1
4. Mortar for floor finish	2

C. Mixing.

30. Mixing, unless otherwise authorized by the engineer, shall be done in a batch mixer of approved type, which will insure a uniform distribution of the materials throughout the mass, so that the mixture is uniform in color and homogeneous. The mixer shall be equipped with suitable charging hopper, water storage, and a water-measuring device controlled from a case which can be kept locked and so constructed that the water can be discharged only while the mixer is being charged. It shall also be equipped with an attachment for automatically locking the discharge lever until the batch has been mixed the required time after all materials are in the mixer. The entire contents of the drum shall be discharged before recharging. The mixer shall be cleaned at frequent intervals while in use. **Machine Mixing.**

31. The mixing of each batch shall continue not less than 1½ minutes after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 ft. per minute. The volume of the mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer. **Time of Mixing.**

32. When hand mixing is authorized by the engineer it shall be done on a water-tight platform. The materials shall be turned at least six times after the water is added and until the batch is homogeneous in appearance and color. **Hand Mixing.**

33. The retempering of concrete or mortar which has partially hardened, that is, remixing with or without additional cement, aggregate or water, shall not be permitted. **Retempering.**

VI. DEPOSITING CONCRETE.

A. Depositing in Air.

34. Before beginning a run of concrete, hardened concrete and foreign materials shall be removed from the inner surfaces of mixing and conveying equipment. **General.**

35. Before depositing concrete, debris shall be removed from the space to be occupied by the concrete; forms shall be thoroughly wetted (except in freezing weather) or oiled. Reinforcement shall be thoroughly secured in position and approved by the engineer. **Approval.**

36. Concrete shall be handled from the mixer to the place of final deposit as rapidly as practicable by methods which shall prevent the separation or loss of the ingredients. It shall be deposited in the forms as nearly as practicable in its final position to avoid rehandling. **Handling.**

It shall be deposited in approximately uniform horizontal layers; the piling up of the concrete in the forms in such manner as to permit the escape of the mortar from the coarse aggregate will not be permitted. Forms for walls or other thin section of considerable height, shall be provided with openings, or other devices that will permit the concrete to be placed in a manner that will avoid accumulations of hardened concrete on forms or metal reinforcement. Under no circumstances shall concrete that has partially hardened be deposited in the work.

Spouting.

37. When concrete is conveyed by spouting, the plant shall be of such size and design as to insure a practically continuous flow in the spout. The angle of the spout with the horizontal shall be such as to allow the concrete to flow without separation of the ingredients.[1] The spout shall be thoroughly flushed with water before and after each run. The delivery from the spout shall be as close as possible to the point of deposit. When operation must be intermittent, the spout shall discharge into a hopper.

Compacting.

38. Concrete, during and immediately after depositing, shall be thoroughly compacted by means of rods or forks. For thin walls or inaccessible portions of the forms where rodding or forking is impracticable, the concrete shall be assisted into place by tapping or hammering the forms. The concrete shall be thoroughly worked around the reinforcement, and around embedded fixtures, into the corners of the forms.

Removal of Water.

39. Water shall be removed from excavations before concrete is deposited unless otherwise directed by the engineer. A continuous flow of water into the excavation shall be diverted through proper side drains to a sump, or by other approved methods which will avoid washing the freshly deposited concrete.

Protection.

40. Exposed surfaces of concrete subjected to premature drying shall be kept thoroughly wetted for a period of at least 7 days.

Cold Weather.

41. Concrete mixed and deposited during freezing weather shall have a temperature of not less than 50° F. nor more than 100° F. Suitable means shall be provided for maintaining a temperature of at least 50° F. for not less than 72 hours after placing, or until the concrete has thoroughly hardened. The methods of heating the materials and protecting the concrete shall be approved by the engineer. Salt, chemicals or other foreign materials shall not be used to prevent freezing.

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[1] An angle of about 27 deg., or one vertical to two horizontal, is good practice. Spouting through a vertical pipe is satisfactory when the flow is continuous; when it is unchecked and discontinuous it is highly objectionable unless the flow is broken by baffles.

Depositing Continuously. 42. Concrete shall be deposited continuously and as rapidly as practicable and until the unit of operation, as approved by the engineer, is completed. Construction joints at points not provided for in the plans shall be made in accordance with the provisions in Section 69.

Bonding. 43. The surface of the hardened concrete shall be roughened and thoroughly cleaned of foreign matter and laitance, and saturated with water and forms retightened before depositing concrete. An excess of mortar on vertical or inclined surfaces shall be secured by thoroughly rodding or forking the freshly deposited concrete to remove the coarse aggregate from contact with the hardened concrete.

B. Rubble and Cyclopean Concrete.

Rubble Concrete. 44. Rubble aggregate shall be thoroughly embedded in the concrete. The individual stones shall not be closer to any surface or adjacent stone than the maximum size of the coarse aggregate plus 1 in. Each successive layer of concrete shall be keyed in accordance with the provision in Section 69.

Cyclopean Concrete. 45. Cyclopean aggregate shall be thoroughly embedded in the concrete; no stone shall be closer to a finished surface than 1 ft., nor closer than 6 in. to any adjacent stone. Stratified stone shall be laid on its natural bed.

C. Depositing Under Water.[1]

General. 46. The methods, equipment, and materials to be used shall be submitted to and approved by the engineer before the work is started. Concrete shall be deposited by a method that will prevent the washing of the cement from the mixture, minimize the formation of laitance and avoid flow of water until the concrete has fully hardened. Concrete shall be placed so as to minimize segregation of materials. Hand mixing will not be permitted. Concrete shall not be placed in water at temperatures below 35° F.

Proportions. 47. Concrete deposited under water shall consist of not less than 1 part of Portland cement to 6 parts of fine and coarse aggregate, measured separately.

Cofferdams. 48. Cofferdams shall be sufficiently tight to prevent flow of water through the space in which concrete is to be deposited. Pumping will not be permitted while concrete is being deposited, nor until it has fully hardened.

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[1] Concrete should not be deposited under water if practicable to deposit in air. There is always uncertainty as to the results obtained from placing concrete under water; where conditions permit, the additional expense and delay of avoiding this method will be warranted. It is especially important that the aggregate be free from loam and other material which may cause laitance. Washed aggregates are preferable. Coarse aggregate consisting of washed gravel of a somewhat smaller size than used in open-air concrete work will give best results. Concrete should never be deposited under water without experienced supervision. Many failures, especially of structures in sea water can be traced directly to ignorance of proper methods or lack of expert supervision.

Depositing Continuously. 49. Concrete shall be deposited continuously, keeping the top surface as nearly level as possible, until it is brought above water, or to the required height. The work shall be carried on with sufficient rapidity to insure bonding of the successive layers.

Method. 50. The following method[1] shall be used for depositing concrete under water:

(*a*) *Tremie.*—The tremie shall be water-tight and sufficiently large to permit a free flow of concrete. It shall be kept filled[2] at all times during depositing. The concrete shall be discharged and spread by raising the tremie in such manner as to maintain as nearly as practicable a uniform flow and avoid dropping the concrete through water. If the charge is lost during depositing the tremie shall be withdrawn and refilled.

(*b*) *Drop-Bottom Bucket.*—The bucket shall be of a type that cannot be dumped until it rests on the surface upon which the concrete is to be deposited. The bottom doors when tripped shall open freely downward and outward. The top of the bucket shall be open. The bucket shall be completely filled, and slowly lowered to avoid back-wash. When discharged, the bucket shall be withdrawn slowly until clear of the concrete.

(*c*) *Bags.*—Bags of jute or other coarse cloth shall be filled about two-thirds full of concrete and carefully placed by hand in a header-and-stretcher system so that the whole mass is interlocked.

Laitance. 51. The concrete shall be disturbed as little as possible while it is being deposited, in order to avoid the formation of laitance. Laitance shall be removed.

VII. FORMS.

General. 52. Forms shall conform to the shape, lines and dimensions of the concrete as called for on the plans. Lumber used in forms for exposed surfaces shall be dressed to a uniform thickness, and shall be free from loose knots or other defects. Joints in forms shall be horizontal or vertical. For unexposed surfaces and rough work, undressed lumber may be used. Lumber once used in forms shall have nails withdrawn, and surfaces to be in contact with concrete thoroughly cleaned, before being used again.

Design. 53. Forms shall be substantial and sufficiently tight to prevent leakage of mortar; they shall be properly braced or tied together so as to maintain position and shape. If adequate foundation for shores cannot be secured, trussed supports shall be provided.

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[1] The engineer should strike out the method or methods inapplicable to the work.

[2] The tremie may be filled by one of the following methods: (1) Place the lower end in a box partly filled with concrete, so as to seal the bottom, then lower into position; (2) plug the tremie with cloth sacks or other material, which will be forced down as the tube is filled with concrete; (3) plug the end of the tremie with cloth sacks filled with concrete.

54. Bolts and rods shall preferably be used for internal ties; they shall be so arranged that when the forms are removed no metal shall be within 1 in. of any surface. Wire ties will be permitted only on light and unimportant work; they shall not be used through surfaces where discoloration would be objectionable. Shores supporting successive stories shall be placed diretly over those below, or so designed that the load will be transmitted directly to them. Forms shall be set to line and grade and so constructed and fastened as to produce true lines. Special care shall be used to prevent bulging. **Workmanship.**

55. Unless otherwise specified, suitable moldings or bevels shall be placed in the angles of forms to round or bevel the edges of the concrete. **Moldings.**

56. The inside of forms shall be coated with non-staining mineral oil, or other approved material, or thoroughly wetted (except in freezing weather). Where oil is used, it shall be applied before the reinforcement is placed. **Oiling.**

57. Temporary openings shall be provided at the base of column and wall forms, and other places where necessary to facilitate cleaning and inspection immediately before depositing concrete. **Inspection of Forms.**

58. Forms shall not be disturbed until the concrete has adequately hardened, nor shall the permanent shores be removed until the structure has attained its full design strength[1] and all excess construction load has been removed. Wall and column forms shall be left in place until the concrete has hardened sufficiently to sustain its own weight and the construction loads likely to come upon it. Forms other than wall or column forms shall be left in place until the concrete has hardened sufficiently to carry the full load which it must sustain, unless removed in sections and each section of the structure is immediately re-shored. **Removal of Forms.**

VIII. DETAILS OF CONSTRUCTION.

A. Metal Reinforcement.

59. Metal reinforcement, before being positioned, shall be thoroughly cleaned of mill and rust scale, and of coatings of any character that will destroy or reduce the bond. Reinforcement appreciably reduced in section shall be rejected. Reinforcement shall **Cleaning.**

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[1] Many conditions affect the hardening of concrete and the proper time for the removal of the forms should be determined by a competent and responsible person.

be re-inspected and when necessary cleaned, where there is delay in depositing concrete.

Bending. 60. Reinforcement shall be carefully formed to the dimensions indicated on the plans or called for in the specifications. The radius of bends shall be 4 or more times the least diameter of the reinforcement bar.

Straightening. 61. Metal reinforcement shall not be bent or straightened in a manner that will injure the material. Bars with kinks or sharp bends shall not be used.

Placing. 62. Metal reinforcement shall be accurately positioned, and secured against displacement by using annealed iron wire of not less than No. 18 gage or suitable clips at intersections, and shall be supported by concrete or metal chairs, or spacers, or by metal hangers. Parallel bars shall not be placed closer in the clear than $1\frac{1}{2}$ times the diameter of round bars or $1\frac{1}{2}$ times the diagonal of square bars; if the ends of bars are hooked as specified in Section 130 the clear spacing may be made equal to the diameter of round bars or to the diagonal of square bars, but in no case shall the spacing between bars be less than 1 in., nor less than $1\frac{1}{4}$ times the maximum size of the coarse aggregate.

Splicing. 63. Splices of tension reinforcement at points of maximum stress shall be avoided. Splices, where required, shall provide sufficient lap to transfer the stress between bars by bond and shear, or by a mechanical connection such as a screw coupling.

Offsets in Column Reinforcement. 64. Vertical reinforcement shall be offset in a region where lateral support is afforded when changes in column cross-section occur and the vertical reinforcement bars are not sloped for the full length of the column.

Future Bonding. 65. Exposed reinforcement bars intended for bonding with future extensions shall be protected from corrosion

B. Concrete Covering over Metal.

Moisture Protection. 66. Metal reinforcement in wall footings and column footings shall have a minimum covering of 3 in. of concrete.

Fire Protection. 67. Metal reinforcement in fire-resistive construction shall be protected by not less than 1 in. of concrete in slabs and walls, and not less than 2 in. in beams, girders and columns, provided aggregate showing an expansion not materially greater than that of limestone or trap rock is used; when impracticable to obtain aggregate of this grade, the protective covering shall be 1 in. thicker and shall be reinforced with metal mesh not exceeding 3 in. in greatest dimensions, placed 1 in. from the finished surface.

The metal reinforcement in structures containing incombustible materials and in bridges where the fire hazard is limited, shall be protected by not less than $\frac{3}{4}$ in. of concrete in slabs and walls and of not less than $1\frac{1}{2}$ in. in beams, girders and columns.

Plaster. 68. Plaster finish on an exposed concrete surface may be allowed to reduce the thickness of concrete protection required in Section 67 by one-half the thickness of the plaster, but the protection shall not be less than that specified in Sections 66 and 67

C. *Joints.*

Construction Joints. 69. Construction joints not indicated on the plans nor specified shall be located and formed so as to least impair the strength and appearance of the structure. Horizontal construction joints shall be formed by embedding stones projecting above the surface or by roughening the surface in contact, or by mortises or keys formed in the concrete. Sufficient section shall be provided in horizontal as well as vertical keys to resist shear.

Joints in Columns. 70. Construction joints in columns shall be made at the underside of the floor. Haunches and column capitals shall be considered as part of and built monolithic with the floor construction.

Joints in Floors. 71. Construction joints in floors shall be located near the center of spans of slabs, beams, and girders, unless a beam intersects a girder at this point, in which case the joints in the girders shall be offset a distance equal to twice the width of the beam. Adequate provision shall be made for shear either by sufficient reinforcement, or by sloping the joint so as to provide an inclined bearing.

Monolithic Construction. 72. Girders and beams designed to be monolithic with walls and columns, shall not be cast until 2 hours after the completion of the walls or columns.

Construction Joints in Long Buildings. 73. Construction joints made crosswise of a building 100 ft. or more in length, shall have special reinforcement placed at right angles to the joint and extending a sufficient distance on each side of the joint to develop the strength of the reinforcement by bond. This reinforcement shall be placed near the opposite face of the member from the main tension reinforcement; the amount of such reinforcement shall be not less than 0.5 per cent of the section of the members cut by the joint.

Expansion Joints. 74. Expansion joints shall be so detailed that the necessary movement may occur with the minimum of resistance at the joint. The structure adjacent to the joint shall preferably be supported on separate columns or walls. Reinforcement shall not extend across an expansion joint. The break between the two sections shall be complete, and may be effected by a coating of white lead and oil, asphalt paint or petrolatum, or by building paper, placed over the entire surface of the hardened concrete. Exposed edges of expansion joints in walls or abutments shall be beveled. Exposed expansion joints formed between two distinct concrete members shall be filled with an elastic joint filler of approved quality.

Expansion Joints in Long Buildings.

75. Structures exceeding 200 ft. in length and of width less than about one-half the length, shall be divided by means of expansion joints, located near the middle, but not more than 200 ft. apart, to minimize the destructive effects of temperature changes and shrinkage. Structures in which marked changes in plan section take place abruptly, or within a small distance, shall be provided with expansion joints at the points where such changes in section occur.

Sliding Joints.

76. The seat of sliding joints shall be finished with a smooth troweled surface and shall not have the superimposed concrete placed upon it until it has thoroughly hardened. In order to facilitate sliding, two thicknesses of building paper shall be placed over the seat on which the superimposed concrete is to be deposited.

Water-tight Joints.

77. When it is not possible to finish a section of the structure in one continuous operation and water-tight construction is required, the joints shall be prepared as follows: The surface of the first section of concrete shall be provided with continuous key-ways. All laitance and other foreign substances shall be removed from the surface of the concrete first placed; this surface shall then be thoroughly satue rated with water and given a heavy coating of neat cement. The next section of concrete shall be placed in such manner as to insuran excess of mortar over the entire surface of the joint. Where shown on the plans, the joint shall be so constructed as to permit of its being caulked with oakum.

IX. WATERPROOFING AND PROTECTIVE TREATMENT.

A. *Waterproofing.*

General.

78. The requirements for quality of concrete in Section 28 shall be strictly followed. Particular attention shall be given to workmanship.

Integral Compounds.

79. Integral compounds shall not be used.

Membrane Waterproofing.

80. Membrane waterproofing shall be used in basements, pits, shafts, tunnels, bridge floors, retaining walls and similar structures, where an added protection is desired.

Water-tight Joints.

81. See Section 77.

B. Oilproofing.

82. Concrete structures for containing light mineral oils, animal oils, certain vegetable oils and other commercial liquids shall be given a special coating which shall be applied immediately after construction. Floors or other surfaces exposed to heavy concentrations of such oils or liquids shall be similarly protected. The treatment to be applied shall be approved by the engineer. **Oilproofing.**

C. Concrete in Sea Water.

83. Plain concrete in sea water or exposed directly along the sea coast shall contain not less than $1\frac{1}{2}$ bbl. (6 bags) of Portland cement per cubic yard in place; concrete from 2 ft. below low water to 2 ft. above high water, or from a plane below to a plane above wave action, shall be made of a mixture containing not less than $1\frac{3}{4}$ bbl. (7 bags) of Portland cement per cubic yard in place. Slag, broken brick, soft limestone, soft sandstone or other porous or weak aggregates shall not be used. **Proportions.**

84. Concrete shall not be deposited under sea water unless unavoidable, in which case it shall be placed in accordance with the methods described in Sections 48 to 51. Sea water should not be allowed to come in contact with the concrete until it has hardened for at least 4 days. Concrete shall be placed in such a manner as to avoid horizontal or inclined seams or work planes. The placing of concrete between tides shall be a continuous operation, in accordance with the methods described in Section 42; where it is impossible to avoid seams or joints proceed as in Section 43. **Depositing.**

85. Metal reinforcement shall be placed at least 3 in. from any plane or curved surface, and at corners at least 4 in. from all adjacent surfaces. Metal chairs, supports, or ties shall not extend to the surface of the concrete. Where unusually severe conditions of abrasion are anticipated, the face of the concrete from 2 ft. below low water to 2 ft. above high water, or from a plane below to a plane above wave action, shall be protected by creosoted timber, dense vitrified shale brick, or stone of suitable quality, as designated on the plans. **Protection.**

86. The consistency shall be such as to produce concrete which for mass work shall give a slump of not more than 2 in., and for reinforced concrete a slump of not more than 4 in. **Consistency**

D. Concrete in Alkali Soils or Water.

87. Concrete below the ground-line shall contain not less than $1\frac{3}{4}$ bbl. (7 bags) of Portland cement per cubic yard in place. **Proportions.**

Consistency. 88. The consistency of the concrete shall be such as to produce a slump of not more than 2 in., and for small members in which aggregates coarser than $\frac{3}{8}$ in. cannot be used, a slump of not more than 6 in.

Placing. 89. Concrete should be placed in such a manner as to avoid horizontal or inclined seams, or work planes; where this is impossible the requirements of Section 69 shall be followed.

Curing. 90. Concrete shall be kept wet with fresh water for not less than 7 days following placing.

Protection. 91. Metal reinforcement or other corrodible metal shall not be placed closer than 2 in. to the faces of members exposed to alkali soil or water.

X. SURFACE FINISH.

General. 92. Concrete to have exposed surfaces with specified finish shall be mixed, placed and worked to secure a uniform distribution of the aggregates, and insure uniform texture of surface.[1] Placing shall be continuous throughout each distinct division of an area. Joint lines shall be located at indicated points. Voids which appear upon removal of the forms shall be drenched with water and be immediately filled with material of the same composition as that used in the surface, and smoothed with a wood spatula or float. Fins or offsets shall be neatly removed. The work shall be finished free from streaks.

Top Surfaces not Subject to Wear. 93. Top surfaces not subject to wear shall be smoothed with a wood float and be kept wet for at least 7 days. Care shall be taken to avoid an excess of water in the concrete, and to drain off or otherwise promptly remove any water that comes to the surface. Dry cement, or a dry mixture of cement and sand, shall not be sprinkled directly on the surface.

A. Wearing Surfaces.

One-Course Work. 94. Aggregates for the wearing surface shall have a high resistance to abrasion. They shall be carefully screened and thoroughly washed. The least quantity of mixing water that will produce a dense concrete shall be used. The mix shall not be leaner than 1 part of Portland cement and $2\frac{1}{2}$ parts of aggregate. The surface shall be screeded even and finished with a wood float. Excess water shall be promptly drained off or otherwise removed. Overtroweling shall be avoided.

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[1] This is accomplished by uniform proportioning of ingredients, and thorough mixing with the proper amount of water; after placing, the concrete should be thoroughly rodded or forked to force the aggregate against the face forms and prevent the formation of voids.

Two-Course Work.

95. In two-course work the wearing surface shall be placed within $\frac{1}{2}$ hour after the base course.

If the wearing surface is required to be applied to a hardened base course, the latter shall be prepared by roughening with a pick or other effective tool, thoroughly drenching with water until saturated and covered with a thin layer of neat cement immediately before the wearing surface is placed.

The finished wearing course in two-course work shall not be thinner than 1 in.

Curing.

96. Concrete wearing surfaces constructed in accordance with Sections 94 and 95, shall be kept wet[1] for at least 10 days in the case of floors and 21 days in the case of roads and pavements.

Terrazzo Finish.

97.[2] Terrazzo finish shall be constructed by mixing 1 part of Portland cement, $2\frac{1}{2}$ parts of crushed marble which will pass through a $\frac{1}{2}$-in. screen and is free from dust, and sufficient water to produce a dense concrete, which shall be spread on the base course and worked down to a thickness of 1 in. by patting or rolling and troweling.

The surface shall be kept wet for not less than 10 days and after thoroughly curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in Section 95.

Terrazzo Finish.

97.[2] Terrazzo finish shall be constructed by mixing 1 part of Portland cement, 2 parts of sand and sufficient water to produce a plastic mortar, which shall be spread on the base course to a depth of 1 in. Crushed marble, which will pass through a $\frac{1}{4}$-in. screen and is free from dust, shall be sprinkled over the surface of the fresh mortar and pressed or rolled in.

The surface shall be kept wet for not less than 10 days and after thoroughly curing shall be rubbed to a plane surface with a stone or a surfacing machine. Hardened concrete to which a terrazzo finish is to be applied shall be prepared as prescribed in Section 95.

B. Decorative Finishes.

Rubbed Finish.

98. Concrete shall be wetted immediately after the forms are removed and rubbed even and smooth with a carborundum brick, or other abrasive, and to uniform appearance without applying any cement or other coating.

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[1] Prevention of premature drying during the early hardening of concrete is essential to the development of high resistance to abrasion. The surface may be covered with a layer of burlap, earth or sand, kept wet, or it may be divided into small areas by dikes and flooded with water to a depth of 2 or 3 in.

[2] The engineer should strike out one of the two Sections numbered 97.

Scrubbed Finish. 99. The face forms shall be removed as soon as the concrete has hardened sufficiently. Voids shall be immediately filled with mortar of the same composition as that used in the face. Fins and other unevennesses shall be rubbed off and the whole surface be scrubbed with fiber or wire brushes, using water freely, as the degree of hardness may require, until the aggregate is uniformly exposed; the surface shall then be rinsed with clean water. The corners shall be sharp and unbroken. If portions of the surface have become too hard to scrub in uniform relief, dilute hydrochloric acid (1 part of acid to 4 parts of water) may be used to facilitate scrubbing of hardened surfaces. The acid shall be thoroughly washed off with clean water.

Sand Blast Finish. 100. Immediately following removal of forms, voids shall be filled with mortar of the same composition as that used in the face and allowed to harden. Unevennesses and form marks shall be removed by chipping or rubbing; the face shall then be cut with an air blast of hard sand with angular grains until the aggregate is in uniform relief.

Tooled Finish. 101. The surface shall be permitted to become hard and dry before tooling. The cutting shall remove the entire skin and produce a uniform surface true to lines.

Sand Floated Finish. 102. The forms shall be removed before the surface has fully hardened; the surface shall be rubbed with a wooden float by a uniform circular motion, using fine sand until the resulting finish is even and uniform.

Colored Aggregate Finish. 103. Colored or other special aggregate used for finish shall be exposed by scrubbing as provided in Section 99. Facing mortar of 1 part of Portland cement, 1½ parts of sand, and 3 parts of screenings or pebbles shall be placed against the face forms to a thickness of about 1 in. sufficiently in advance of the body concrete to prevent the latter coming in contact with the form.

Colored Pigment Finish. 104. Mineral pigment shall be thoroughly mixed dry with the Portland cement and fine aggregate; care shall be taken to secure a uniform tint throughout.

XI. DESIGN.

A. General Assumptions.

General Assumptions. 105. The design of reinforced concrete members under these specifications shall be based on the following assumptions:

(*a*) Calculations are made with reference to working stresses and safe loads rather than with reference to ultimate strength and ultimate loads.

(*b*) A plane section before bending remains plane after bending.

(*c*) The modulus of elasticity of concrete in compression is constant within the limits of working stresses; the distribution of compressive stress in beams is therefore rectilinear.

(*d*) The values for the modulus of elasticity of concrete in computations for the position of the neutral axis, for the resisting moment of beams and for compression of concrete in columns, are as follows:

(1) 1/40 that of steel, when the compressive strength of the concrete at 28 days is below 800 lb. per sq. in.;

(2) 1/15 that of steel, when the compressive strength of the concrete at 28 days lies between 800 and 2200 lb. per sq. in.;

(3) 1/12 that of steel, when the compressive strength of the concrete at 28 days lies between 2200 and 2900 lb. per sq. in.;

(4) 1/10 that of steel, when the compressive strength of the concrete at 28 days is higher than 2900 lb. per sq. in.;

(5) 1/8 that of steel for calculating the deflection of reinforced concrete beams which are free to move longitudinally at the supports, and in which the tensile resistance of the concrete is neglected.

(*e*) In calculating the moment of resistance of reinforced concrete beams and slabs the tensile resistance of the concrete is neglected.

(*f*) The adhesion between the concrete and the metal reinforcement remains unbroken throughout the range of working stresses. Under compression the two materials are therefore stressed in proportion to their moduli of elasticity.

(*g*) Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected, except in the design of reinforced concrete columns.

B. Flexure of Rectangular Reinforced Concrete Beams and Slabs.

Flexure Formulas.

106. Computations of flexure in rectangular reinforced concrete beams and slabs shall be based on the following formulas:

(*a*) *Reinforced for Tension Only.*

Position of neutral axis.

$$k=\sqrt{2pn+(pn)^2}-pn \quad \cdots\cdots\cdots\cdots\cdots\cdots (1)$$

Arm[1] of resisting couple,

$$j = 1 - \frac{k}{3} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Compressive unit stress[1] in extreme fiber of concrete,

$$f_c = \frac{2M}{jkbd^2} = \frac{2pf_s}{k} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Tensile unit stress[1] in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} = \frac{M}{pjbd^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Steel ratio for balanced reinforcement,

$$p = \frac{1}{2} \frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nf_c} + 1\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

For formulas on shear and bond, see Sections 120 and 140.

(b) *Reinforced for Both Tension and Compression.*
Position of neutral axis,

$$k = \sqrt{2n\left(p + p'\frac{d'}{d}\right) + n^2(p+p')^2} - n(p+p') \quad \ldots\ldots\ldots \quad (6)$$

Position of resultant compression,

$$z = \frac{\frac{1}{3}k^3d + 2p'nd'\left(k - \frac{d'}{d}\right)}{k^2 + 2p'n\left(k - \frac{d'}{d}\right)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Arm[1] of resisting couple,

$$jd = d - z \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Compressive unit stress[1] in extreme fiber of concrete,

$$f_c = \frac{6M}{bd^2\left[3k - k^2 + \frac{6p'n}{k}\left(k - \frac{d'}{d}\right)\left(1 - \frac{d'}{d}\right)\right]} \quad \ldots\ldots\ldots\ldots \quad (9)$$

Tensile unit stress[1] in longitudinal reinforcement,

$$f_s = \frac{M}{pjbd^2} = nf_c\frac{1-k}{k} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (10)$$

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[1] For $f_s = 16{,}000$ to 18,000 lb. per sq. in. and $f_c = 800$ to 900 lb. per sq. in., j may be assumed as 0.86. For values of pn varying from 0.04 to 0.24, jk is approximately equal to $0.67\sqrt[3]{pn}$.

Compressive unit stress[1] in longitudinal reinforcement,

$$f'_s = nf_c \frac{k - \frac{d'}{d}}{k} \qquad (11)$$

107. The symbols[2] used in Formulas 1 to 23 are defined as follows: **Notation.**

A_s = effective cross-sectional area of metal reinforcement in tension in beams;

b = width of rectangular beam or width of flange of T-beam;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

f_c = compressive unit stress in extreme fiber of concrete;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth d;

k = ratio of depth of neutral axis to depth d;

l = span length of beam or slab (generally distance from center to center of supports—see Section 108);

M = bending moment or moment of resistance in general;

n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams = A_s/bd;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

w = uniformly distributed load per unit of length of beam or slab;

z = depth from compression surface of beam or slab of resultant of compressive stresses.

108. The span length, l, of freely supported beams and slabs, shall be the distance between centers of the supports, but shall not exceed the clear span plus the depth of beam or slab. The span length for continuous or restrained beams built monolithically with supports shall be the clear distance between faces of supports. Where brackets having a width not less than the width of the beam and making an **Span Length.**

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[1] See footnote, p. 244.

[2] For illustration of notation as applied to typical beams or slabs, see Figs. 1 and 2.

angle of 45 deg. or more with the axis of a restrained beam are built monolithic with the beam and support, the span shall be measured from the section where the combined depth of the beam and bracket is at least one-third more than the depth of the beam. Maximum negative moments are to be considered as existing at the ends of the span, as above defined. No portion of a bracket shall be considered as adding to the effective depth of the beam.

Moments in Freely Supported Beams of Equal Span.

109. The following moments at critical sections of freely supported beams and slabs of equal spans carrying uniformly distributed loads shall be used:

(*a*) Maximum positive moment in beams and slabs of one span,

$$M = \frac{wl^2}{8} \quad \text{(12)}$$

(*b*) Center of slabs and beams continuous for two spans only,

(1) Positive moment at the center,

$$M = \frac{wl^2}{10} \quad \text{(13)}$$

(2) Maximum negative moment,

$$M = \frac{wl^2}{8} \quad \text{(14)}$$

(*c*) Slabs and beams continuous for more than two spans,

(1) Center and supports of interior spans,

$$M = \frac{wl^2}{12} \quad \text{(15)}$$

(2) Center and interior support of end spans,

$$M = \frac{wl^2}{10} \quad \text{(16)}$$

(*d*) Negative moment at the supports of slab or beam built into brick or masonry walls in a manner that develops partial end restraint,

$$M = \text{not less than } \frac{wl^2}{16} \quad \text{(17)}$$

Moments in Beams Monolithic with Supports.

110. The following moments at the critical sections of beams or slabs of equal spans cast monolithic with columns or similar supports and carrying uniformly distributed loads shall be used:

(*a*) Supports of intermediate spans,

$$M = \frac{wl^2}{12} \quad \text{(18)}$$

(*b*) Center of intermediate spans,

$$M = \frac{wl^2}{16} \quad \text{(19)}$$

(*c*) Beams in which I/l is less than twice the sum of the values of I/h for the exterior columns above and below which are built into the beam,

(1) Center and first interior support,

$$M = \frac{wl^2}{12} \quad \text{(20)}$$

(2) Exterior supports,

$$M = \frac{wl^2}{12} \quad \text{(21)}$$

(*d*) Beams in which I/l is equal to, or greater than, twice the sum of the values of I/h for the exterior columns above and below which are built into the beam,

(1) Center of span and at first interior support of end span,

$$M = \frac{wl^2}{10} \quad \text{(22)}$$

(2) Exterior support,

$$M = \frac{wl^2}{16} \quad \text{(23)}$$

Moment Coefficients of Continuous Beams.

111. Continuous beams with unequal spans, whether freely supported or cast monolithic with columns, shall be analyzed to determine the actual moments under the given conditions of loading and restraint. Provision shall be made for negative moment occurring in short spans adjacent to longer spans when the latter only are loaded.

C. *Flexure of Reinforced Concrete T-Beams.*

Flexure Formulas.

112. Computations of flexure in reinforced concrete T-beams shall be based on the following formulas:

(*a*) *Neutral Axis in the Flange.*

Use formulas for rectangular beams and slabs in Section 106.

(*b*) *Neutral Axis below the Flange.*[1]

Position of neutral axis,

$$kd = \frac{2ndA_s + bt^2}{2nA_s + 2bt} \quad \ldots\ldots (24)$$

Position of resultant compression,

$$z = \left(\frac{3kd - 2t}{2kd - t}\right)\frac{t}{3} \quad \ldots\ldots (25)$$

Arm of resisting couple,

$$jd = d - z \quad \ldots\ldots (26)$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{Mkd}{bt(kd - \frac{1}{2}t)jd} = \frac{f_s}{n}\left(\frac{k}{1-k}\right) \quad \ldots\ldots (27)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \quad \ldots\ldots (28)$$

Formulas 24, 25, 26, 27 and 28 neglect compression in the stem.[2]

Notation. 113. The symbols[3] used in Formulas 24 to 28 are defined in Section 107, except as follows:

b' = width of stem of T-beam;
t = thickness of flange of T-beam;

Flange Width. 114. Effective and adequate bond and shear resistance shall be provided in beam-and-slab construction at the junction of the beam and slab; the slab shall be built and considered an integral part of the beam; the effective flange width shall not exceed one-fourth of the span length of the beam, and its overhanging width on either side

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[1] For approximate results the formulas for rectangular beams, Section 106, may be used.

[2] The following formulas take into account the compression in the stem; they are recommended where the flange is small compared with the stem:

Position of neutral axis,

$$kd = \sqrt{\frac{2ndA_s + (b-b')t^2}{b'} + \left(\frac{nA_s + (b-b')t}{b'}\right)^2} - \frac{nA_s + (b-b')t}{b'} \quad \ldots\ldots (24a)$$

Position of resultant compression,

$$z = \frac{(kdt^2 - \frac{2}{3}t^3)b + [(kd-t)^2(t + \frac{1}{3}(kd-t))]b'}{t(2kd-t)b + (kd-t)^2b'} \quad \ldots\ldots (25a)$$

Arm of resisting couple (see footnote Section 106),

$$jd = d - z \quad \ldots\ldots (26a$$

Compressive unit stress in extreme fiber of concrete,

$$f_c = \frac{2Mkd}{[(2kd-t)bt + (kd-t)^2b']\,jd} \quad \ldots\ldots (27a)$$

Tensile unit stress in longitudinal reinforcement,

$$f_s = \frac{M}{A_s jd} \quad \ldots\ldots (28a)$$

[3] For illustration of certain symbols as applied to typical T-beams, see Fig. 3.

of the web shall not exceed 8 times the thickness of the slab nor one-half the clear distance to the next beam.

Flange Length. 115. The unsupported length of the compression flange of a T-beam shall not exceed 36 times the least width of the beam.

Transverse Reinforcement. 116. Where the principal slab reinforcement is parallel to the beam, transverse reinforcement, not less in amount than 0.3 per cent of the sectional area of the slab, shall be provided in the top of the slab and shall extend over the beam and into the slab not less than two-thirds of the effective flange overhang. The spacing of the bars shall not exceed 18 in.

Compressive Stress in Supports. 117. Provision shall be made for the compressive stress at the support in continuous T-beam construction.

Shear. 118. The flange of the slab shall not be considered as effective in computing the shear and diagonal tension resistance of T-beams.

Isolated Beams. 119. Isolated beams in which the T-form is used only for the purpose of providing additional compression area, shall have a flange thickness not less than one-half the width of the web and a total flange width not more than 4 times the web thickness.

D. Diagonal Tension and Shear.

a. Formulas and Notation.

Formulas. 120. Diagonal tension and shear in reinforced concrete beams shall be calculated by the following formulas:

Shearing unit stress,[1]

$$v = \frac{V}{bjd} \qquad (29)$$

Stress[1] in vertical web reinforcement,

$$f_v = \frac{V's}{A_v jd} \qquad (30)$$

Notation. 121. The symbols used in Formulas 29 to 36 are defined in Section 107, except as follows:

a = spacing of web reinforcement bars measured perpendicular to their direction;

A_v = total area of web reinforcement in tension within a distance of a (a_1, a_2, a_3, etc.) or the total area of all bars bent up in any one plane;

α = angle between web bars and longitudinal bars;

f_v = tensile unit stress in web reinforcement;

o = perimeter of bar;

Σo = sum of perimeters of bars in one set;

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[1] Approximate results may be secured by assuming $j = 0.875$.

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips;

s = spacing of web members, measured at the neutral axis and in the direction of the longitudinal axis of the beam;

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

V' = external shear on any section after deducting that carried by the concrete.

b. Beams Without Web Reinforcement.

Bars Not Anchored.

122. The shearing unit stress in beams in which the longitudinal reinforcement is designed to meet all moment requirements, but without special anchorage, shall not exceed 0.02 f'_c, but in no case shall it exceed 40 lb. per sq. in. Adequate reinforcement shall be provided at all sections where negative moment occurs in beams continuous over supports or built into walls or columns at their ends. (For typical design, see Fig. 4.)

Bars Anchored.

123. The shearing unit stress in beams in which longitudinal reinforcement is anchored by means of hooked ends or otherwise, as specified in Section 130, shall not exceed 0.03 f'_c. Adequate reinforcement for both positive and negative moment shall be provided at all sections where maximum moment exists. (For typical design, see Fig. 5.)

c. Beams With Web Reinforcement.

With Web Reinforcement.

124. When the shearing unit stress calculated by Formula 29 exceeds the values specified in Sections 122 and 123, web reinforcement shall be provided by one or more of the following methods:

(*a*) Series of vertical stirrups or web bars;
(*b*) Series of inclined stirrups or web bars;
(*c*) Series of bent-up longitudinal bars;
(*d*) Longitudinal bars bent up in a single plane.

Provision against bond failure of the web reinforcement shall be as specified in Section 131. (For typical designs, see Figs. 6 and 7. For typical detail of anchorage of longitudinal bars and vertical stirrups, see Fig. 8.)

Web or Bent-up Bars.

125. Where web reinforcement is present and where longitudinal reinforcement is provided to meet all moment requirements, the concrete may be assumed to carry a shearing unit stress not greater than

$0.02 f'_c$ and not greater in any case than 40 lb. per sq. in. In the case where a series of web bars or bent-up longitudinal bars is used, the web reinforcement shall be designed according to the formula:

$$A_v = \frac{V'a}{f_v jd} = \frac{V's \sin \alpha}{f_v jd} \qquad (31)$$

(For typical design, see Fig. 9.)

Bars Bent Up in Single Plane.

126. Where the web reinforcement consists of bars bent up in a single plane at an angle so as to reinforce all sections of the beam in which the shearing unit stress on the web concrete exceeds $0.02 f'_c$, the concrete may be assumed to take a shearing unit stress not greater than $0.02 f'_c$, and not greater than 40 lb. per sq. in.; the remainder of the shear shall be carried by the bent-up bars designed according to the formula:

$$A_v = \frac{V'}{f_v \sin \alpha} \qquad (32)$$

In case the web reinforcement consists solely of bent bars, the first bent bar shall bend downward from the plane of the upper reinforcement at the plane of the edge of the support or between that plane and the center of the support. (For typical design, see Fig. 10.)

Combined Web Reinforcement.

127. Where two or more types of web reinforcement are used in conjunction, the total shearing resistance of the beam shall be taken as the sum of the shearing resistance as computed for the various types separately.[1]

Maximum Shearing Unit Stress.

128. Where there is no special mechanical anchorage of the longitudinal reinforcement, the shearing unit-stress shall not exceed $0.06 f'_c$ irrespective of the web reinforcement used.

Special Mechanical Anchorage.

129. Where special mechanical anchorage of the longitudinal reinforcement as prescribed in Section 130 is provided, the shearing unit stress as computed by Formula 29 may be greater than $0.06 f'_c$, but in no case shall it exceed $0.12 f'_c$.[2] In this case the concrete may be assumed to take a shearing unit stress of not more than $0.025 f'_c$, but not more than 50 lb. per sq. in.

Anchorage of Longitudinal Reinforcement.

130. Special mechanical anchorage of the longitudinal reinforcement for positive moment may consist of carrying the bars beyond the point of inflection of restrained or continuous members a sufficient distance to develop by bond between the point of inflection and the end of the bar a tensile stress equal to one-third the safe working

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[1] In such computation the shearing value of the concrete in the web shall be included once only.

[2] The limit $0.12 f'_c$ is based on the ultimate bearing unit stress of $0.5 f'_c$ at which beams reinforced with vertical stirrups fail due to diagonal compression in the webs. A higher value than $0.12 f'_c$ may be permitted in beams with inclined web reinforcement, but it is not thought necessary to allow such higher limit to meet the needs of design practice.

stress in the reinforcement. If such a bar is straight, it shall extend to within 1 in. of the center of the support, or in the case of wide supports shall extend not less than 12 in. beyond the face of the support. Special mechanical anchorage may also be secured by bending the end of the bar over the support in a full semi-circle to a diameter not less than 8 times the diameter of the bar, the total length of the bend being not less than 16 diameters of the bar. Any other mechanical device that secures the end of the bar over the support against slipping without stressing the concrete in excess of 0.5 f'_c in local compression may be used, provided such device does not tend to split the concrete. Negative reinforcement shall be thoroughly anchored at or across the support or shall extend into the span a sufficient distance to develop by bond the tensile stresses due to negative moment. In the case of freely supported ends of continuous beams, special mechanical anchorage shall be provided, which is capable of developing at the end of the span a tensile stress which is not less than one-third of the safe tensile stress of the bar at the point of maximum moment. (For illustrative design, see Fig. 11.)

Anchorage of Web Reinforcement.

131. Anchorage of the web reinforcement shall be by one of the following methods:

(*a*) Continuity of the web bar with the longitudinal bar;

(*b*) Carrying the web bar around at least two sides of a longitudinal bar at both ends of the web bar; or

(*c*) Carrying the web bar about at least two sides of a longitudinal bar at one end and making a semi-circular hook at the other end which has a diameter equal to that of the web bar.

In all cases the bent ends of web bars shall extend at least 8 diameters below or above the point of extreme height or depth of the web bar. In case the end anchorage of the web member is not in bearing on other reinforcement, the anchorage shall be such as to engage an adequate amount of concrete to prevent the bar from pulling off a portion of the concrete. In all cases the stirrups shall be carried as close to the upper and lower surfaces as fireproofing requirements will permit. (For typical designs, see Figs. 8 and 12.)

Size of Web Bars.

132. The size of web reinforcement bars which are neither a part of the longitudinal bars nor welded thereto, shall be such that not less than two-fifths of the allowable tensile stress in the bar may be developed by bond stresses in a length of bar equal to 0.4 d.[1] The remainder of the tensile stress in the bar shall be provided for by adequate end anchorage as specified in Section 131.

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[1] This condition is satisfied for plain round stirrups when the diameter of the bar does not exceed $d/50$.

133. Shearing unit stress shall be computed on the full width of rectangular beams, on the width of the stem of T-beams, and on the thickness of the web in beams of I-section. **Breadth of Beams in Shear.**

134. The shearing stress in tile-and-concrete-beam construction shall not exceed that in beams or slabs with similar reinforcement. The width of the effective section for shear as governing diagonal tension shall be taken as the thickness of the concrete web plus one-half the thickness of the vertical webs of the tile. (For typical design, see Fig. 13.) **Shear in Beam-and-Tile Construction.**

135. The spacing, a, of web reinforcement bars shall be measured perpendicular to their direction and in a plane parallel to the longitudinal axis of the beam. The spacing shall not exceed $\frac{3}{4}d$ in any case where web reinforcement is necessary. Where vertical stirrups are used, or where inclined web bars make an angle more than 60 deg. with the horizontal, the spacing shall not exceed $\frac{1}{2}d$. Where the shearing unit stress exceeds $0.06 f'_c$, the spacing of the web reinforcement shall not exceed $\frac{1}{2}d$ in any case, nor $\frac{1}{3}d$ for vertical stirrups or web reinforcement making an angle more than 60 deg. with the horizontal. The first shear reinforcement member shall cross the neutral axis of the member at a distance from the face of the support, measured along the axis of the beam, not greater than $\frac{1}{4}d$, nor greater than the spacing of web members as determined for a section taken at the edge of the support. Web members may be placed at any angle between 20 and 90 deg. with the longitudinal bars, provided that if inclined they shall be inclined in such a manner as to resist the tensile stress in the web. **Spacing of Web Reinforcement.**

d. Flat Slabs.

136. The shearing unit stress shall not exceed the value of v in the formula, **Shearing Stress.**

$$v = 0.02\, f'_c\,(1+r) \qquad (33)$$

nor in any case shall it exceed $0.03\, f'_c$.

The unit shearing stress shall be computed on

(*a*) A vertical section which has a depth in inches of $\frac{7}{8}\,(t_1 - 1\frac{1}{2})$ and which lies at a distance in inches of $t_1 - 1\frac{1}{2}$ from the edge of the column capital; and

(*b*) A vertical section which has a depth in inches of $\frac{7}{8}\,(t_2 - 1\frac{1}{2})$ and which lies at a distance in inches of $t_2 - 1\frac{1}{2}$ from the edge of the dropped panel.

In no case shall r be less than 0.25. Where the shearing stress on section (*a*) is being considered, r shall be taken as the proportional amount of reinforcement crossing the column capital; where the shearing stress at section (*b*) is being considered, *r* shall be taken as the proportional amount of reinforcement crossing entirely over the dropped panel. (For typical flat slab and designation of principal design sections, see Figs. 14 and 15.)

e. Footings.

Shear and Diagonal Tension in Footings.

137. The shearing stress shall be computed by Formula 29. When so computed the stress on the critical section defined below, or on sections outside of the critical section, shall not exceed 0.02 f'_c for footings with straight reinforcement bars, nor 0.03 f'_c for footings in which the reinforcement bars are anchored at both ends by adequate hooks or otherwise as specified in Section 130.

Critical Section for Soil Footings.

138. The critical section for diagonal tension in footings bearing directly on the soil shall be taken on a vertical section through the perimeter of the lower base of a frustum of a cone or pyramid which has a base angle of 45 deg. and has for its top the base of the column or pedestal and for its lower base the plane of the center of longitudinal reinforcement.

Critical Section for Pile Footings.

139. The critical section for diagonal tension in footings bearing on piles shall be taken on a vertical section at the inner edge of the first row of piles entirely outside a section midway between the face of the column or pedestal and the section described in Section 138 for soil footings, but in no case outside of the section described in Section 138. The critical section for piles not grouped in rows shall be taken midway between the face of the column and the perimeter of the base of the frustum described in Section 138.

E. Bond.

Formula.

140. Bond between concrete and reinforcement bars in reinforced concrete beams and slabs shall be computed by the formula,

$$u = \frac{V}{\Sigma o\, jd} \qquad \text{(34)}$$

Working Stress.

141. Unless otherwise specified, the reinforcement shall be so proportioned that the bond stress between the metal and the concrete shall not exceed the following:

(*a*) Plain bars,

$$u = 0.04\, f'_c \qquad \text{(35)}$$

(*b*) Deformed bars, meeting the requirements of Section 23,

$$u = 0.05\, f'_c \qquad \text{(36)}$$

Bond in Footings.

142. The bond stress on a section of a footing shall be computed by Formula 34. Only the bars counted as effective in bending shal

be considered in computing the number of bars crossing a section. The bond stress computed in this manner on sections at the face of the column or outside the column shall not exceed the value specified in Section 141. Special investigation shall be made of bond stresses in footings with stepped or sloping upper surface; maximum stresses may occur at sections near the edges of the footings.

Reinforcement in Two or More Directions.

143. The permissible bond stress given by Formulas 35 and 36 for footings and similar members where reinforcement is required in more than one direction shall be reduced as follows:

(*a*) For two-way reinforcement, 25 per cent;

(*b*) For each additional direction, 10 per cent.

Anchored Bars.

144. The bond stresses for bars adequately anchored at both ends by hooks or otherwise, as provided in Section 130, may be $1\frac{1}{2}$ times the values specified in Section 141. Hooks in footings shall be effectively positioned to insure that they engage a mass of concrete above the plane of the reinforcement.

F. Flat Slabs.[1]

Moments in Interior Panels.

145. The symbols used in Formulas 37 to 42 are defined in Section 107 except as indicated in Sections 145, 148 and 158. In flat slabs in which the ratio of reinforcement for negative moment in the column strip is not greater than 0.01, the numerical sum of the positive and negative moments in the direction of either side of the panel shall be taken as not less than

$$M_0 = 0.09\ Wl\left(1-\frac{2}{3}\frac{c}{l}\right)^2 \ldots\ldots\ldots\ldots\ldots\ldots (37)$$

where M_0 = sum of positive and negative bending moments in either rectangular direction at the principal design sections of a panel of a flat slab;

= base diameter of the largest right circular cone, which lies entirely within the column (including the capital) whose vertex angle is 90 deg. and whose base is $1\frac{1}{2}$ in. below the bottom of the slab or the bottom of the dropped panel (see Fig. 14);

l = span length[2] of flat slab, center to center of columns in the rectangular direction in which moments are considered; and

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[1] The requirements for flat slabs in Sections 145 to 162, inclusive, apply to two-way and four-way systems of reinforcement. The Committee is not prepared at this time to submit requirements covering other types of flat slabs.

[2] The column strip and the middle strip to be used when considering moments in the direction of the dimension l are located and dimensioned as shown in Fig. 15. The dimension l_1 does not always represent the short length of the panel. When moments in the direction of the shorter panel length are considered, the dimensions l and l_1 are to be interchanged and the strips corresponding to those shown in Fig. 15 but extending in the direction of the shorter panel length are to be considered.

W = total dead and live load uniformly distributed over a single panel area.

Principal Design Sections.

146. The principal design sections for critical moments in flat slabs subjected to uniform load shall be taken as follows:

(*a*) Negative moment in middle strip: extending in a rectangular direction from a point on the edge of panel $l_1/4$ from column center a distance $l_1/2$ toward the center of adjacent column on the same panel edge.

(*b*) Negative moment in column strip: extending in a rectangular direction along the edge of the panel from a point $l_1/4$ from the center of a column to a point $c/2$ from the center of the same column and thence one-quarter circumference about the column center to the adjacent edge of the panel.

TABLE III.—MOMENTS TO BE USED IN DESIGN OF FLAT SLABS.

Strip.	Flat Slabs without Dropped Panels.		Flat Slabs with Dropped Panels.	
	Negative.	Positive.	Negative.	Positive.
SLABS WITH 2-WAY REINFORCEMENT.				
Column strip	0.23 M_0	0.11 M_0	0.25 M_0	0.10 M_0
2 Column strips	0.46 M_0	0.22 M_0	0.50 M_0	0.20 M_0
Middle strip	0.16 M_0	0.16 M_0	0.15 M_0	0.15 M_0
SLABS WITH 4-WAY REINFORCEMENT.				
Column strip	0.25 M_0	0.10 M_0	0.27 M_0	0.095 M_0
2 Column strips	0.50 M_0	0.20 M_0	0.54 M_0	0.190 M_0
Middle strip	0.10 M_0	0.20 M_0	0.08 M_0	0.190 M_0

(*c*) Positive moment in middle strip: extending in a rectangular direction from the center of one edge of a middle strip a distance $l_1/2$ to the center of the other edge of the same strip.

(*d*) Positive moment in column strip: extending in a rectangular direction from the center of one edge of a column strip a distance $l_1/4$ to the center of the other edge of the same strip.

Moments in Principal Design Sections.

147. The moments in the principal design sections shall be those given in Table III, except as follows:

(*a*) The sum of the maximum negative moments in the two column strips may be greater or less than the values given in Table III, by not more than 0.03 M_0.

(*b*) The maximum negative moment and the maximum positive moments in the middle strip and the sum of the maximum positive moments in the two column strips may each be greater or less than the values given in Table III, by not more than $0.01\ M_0$.

Thickness of Flat Slabs and Dropped Panels.

148. The total thickness,[1] t_1, of the dropped panel in inches, or of the slab if a dropped panel is not used, shall be not less than:

$$t_1 = 0.0382\left(1 - 1.44\frac{c}{l}\right) l \sqrt{Rw'\frac{l_1}{b_1}} + 1\frac{1}{2} \ldots\ldots\ldots\ldots (38)^2$$

where R = ratio of negative moment in the two column strips to M_0, and w' = uniformly distributed dead and live load per unit of area of floor.

For slabs with dropped panels the total thickness[1] in inches at points away from the dropped panel shall be not less than:

$$t_2 = 0.02\, l \sqrt{w'} + 1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (39)$$

The slab thickness t_1 or t_2 shall in no case be less than $l/32$ for floor slabs, and not less than $l/40$ for roof slabs. In determining minimum thickness by Formulas 38 and 39, the value of l shall be the panel length center to center of the columns, on long side of panel, l_1 shall be the panel length on the short side of the panel, and b_1 shall be the width or diameter of dropped panel in the direction of l_1 except that in a slab without dropped panel b_1 shall be $0.5\, l_1$.

Minimum Dimensions of Dropped Panels.

149. The dropped panel shall have a length or diameter in each rectangular direction of not less than one-third the panel length in that direction, and a thickness not greater than $1.5\, t_2$.

Wall and Other Irregular Panels.

150. In wall panels and other panels in which the slab is discontinuous at the edge of the panel, the maximum negative moment one panel length away from the discontinuous edge and the maximum positive moment between shall be taken as follows:

(*a*) Column strip perpendicular to the wall or discontinuous edge, 15 per cent greater than that given in Table III.

(*b*) Middle strip perpendicular to wall or discontinuous edge, 30 per cent greater than that given in Table III.

In these strips the bars used for positive moments perpendicular to the discontinuous edge shall extend to the exterior edge of the panel at which the slab is discontinuous.

Panels with Wall Beams.

151. In panels having a marginal beam on one edge or on each

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[1] The thickness will be in inches regardless of whether l and w' are in feet and pounds per square foot or in inches and pounds per square inch.

[2] The values of R used in this formula are the coefficients of M_0 for negative moment in the column strip in Table III.

of two adjacent edges, the beam shall be designed to carry the load superimposed directly upon it. If the beam has a depth greater than the thickness of the dropped panel into which it frames, the beam shall be designed to carry, in addition to the load superimposed upon it, at least one-fourth of the distributed load for which the adjacent panel or panels are designed, and each column strip adjacent to and parallel with the beam shall be designed to resist a moment at least one-half as great as that specified in Table III for a column strip.[1] If the beam used has a depth less than the thickness of the dropped panel into which it frames, each column strip adjacent to and parallel with the beam shall be designed to resist the moments specified in Table III for a column strip. Where there are beams on two opposite edges of the panel, the slab and the beam shall be designed as though all the load was carried to the beam.

Discontinuous Panels. 152. The negative moments on sections at and parallel to the wall, or discontinuous edge of an interior panel, shall be determined by the conditions of restraint.[2]

Flat Slabs on Bearing Walls. 153. Where there is a beam or a bearing wall on the center line of columns in the interior portion of a continuous flat slab, the negative moment at the beam or wall line in the middle strip perpendicular to the beam or wall shall be taken as 30 per cent greater than the moment specified in Table III for a column strip. The column strip adjacent to and lying on either side of the beam or wall shall be designed to resist a moment at least one-half of that specified in Table III for a column strip.

Point of Inflection. 154. The point of inflection in any line parallel to a panel edge in interior panels of symmetrical slabs without dropped panels shall be assumed to be at a distance from the center of the span equal to $\frac{3}{16}$ of the distance between the two sections of critical negative moment at opposite ends of the line; for slabs having dropped panels, the coefficient shall be $\frac{1}{4}$.

Reinforcement. 155. The reinforcement bars which cross any section and which fulfill the requirements given in Section 156 may be considered as effective in resisting the moment at the section. The sectional area of a bar multiplied by the cosine of the angle between the direction of the axis of the bar and any other direction may be considered effective as reinforcement in that direction.

Arrangement of Reinforcement. 156. The design shall include adequate provision for securing the reinforcement in place so as to take not only the critical moments but the moments at intermediate sections. All bars in rectangular or diagonal directions shall extend on each side of a section of critical moment, either positive or negative, to points at least 20 diameters beyond the point of inflection as specified in Section 154. In addition to this provision, bars in diagonal directions used as reinforcement for negative moment shall extend on each side of a line drawn through the column center at right angles to the direction of the band at least a distance of 0.35 of the panel length, and bars in diagonal directions used as reinforcement for positive moment shall extend on each side of a diagonal through the center of the panel at least a distance equal to 0.35 of the panel length; no splice by lapping shall be permitted at or near regions of maximum stress except as just described. At least two-thirds of all bars in each direction shall be of such length and shall be so placed as to provide reinforcement at two sections of critical negative moment and at the intermediate section of critical positive moment. Continuous bars shall not all be bent up at the same point of their length, but the zone in which this bending occurs shall extend on each side of the assumed point of inflection, and shall cover a width of at least $\frac{1}{15}$ of the panel length. Mere sagging of the bars shall not be permitted. In four-way reinforcement the position of the bars in both diagonal and rectangular directions may be considered in determining whether the width of zone of bending is sufficient.

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[1] In wall columns, brackets are sometimes substituted for capitals or other changes are made in the design of the capital. Attention is directed to the necessity for taking into account the change in the value of *c* in the moment formula for such cases.

[2] The committee is not prepared to make a more definite recommendation at this time.

Reinforcement at Construction Joints.

157. See Section 73.

Tensile Stress in Reinforcement.

158. The following formula shall be used in computing the tensile stress f_s in the reinforcement in flat slabs; the stress so computed shall not at any of the principal design sections exceed the values specified in Section 205:

$$f_s = \frac{RM_0}{A_s jd} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (40)$$

where RM_0 = moment specified in Section 147 for two column strips or for one middle strip; and

A_s = effective cross-sectional area of the reinforcement which crosses any of the principal design sections and which meets the requirements of Section 156.

Compressive Stress in Concrete.

159. The following formulas shall be used in computing maximum compressive stress in the concrete in flat slabs; and the stress so computed shall not exceed $0.4 f'_c$:

(*a*) Compression due to negative moment, RM_0, in the two column strips,

$$f_c = \frac{3.5\ RM_0}{kjb_1d^2}\left(1 - 1.2\,\frac{c}{l}\right) \quad \ldots\ldots\ldots\ldots (41)$$

(*b*) Compression due to positive moment, RM_0, in the two column strips or negative or positive moment in the middle strip,

$$f_c = \frac{6\ RM_0}{kjl_1d^2} \ldots\ldots\ldots\ldots\ldots\ldots (42)$$

Shearing Stress. 160. See Section 136.

Unusual Panels. 161. The moment coefficients, moment distribution and slab thicknesses specified herein are for slabs which have three or more rows of panels in each direction, and in which the panels are approximately uniform in size. For structures having a width of one or two panels, and also for slabs having panels of markedly different sizes, an analysis shall be made of the moments developed in both slab and columns, and the values given herein modified accordingly. Slabs with paneled ceiling or with depressed paneling in the floor shall be considered as coming under the requirements herein given.

Bending Moments in Columns. 162. See Section 173.

G. *Reinforced Concrete Columns.*

Limiting Dimensions. 163. The provisions in the following sections for the carrying capacity of reinforced columns are based on the assumption of a short column. Where the unsupported length is greater than 40 times the least radius of gyration (40 *R*), the carrying capacity of the column shall be determined by Formula 48 for slender columns. Principal columns in buildings shall have a width of not less than 12 in. Posts that are not continuous from story to story shall have a width of not less than 6 in.

Unsupported Length. 164. The unsupported length of a column in flat slab construction shall be taken as the clear distance between the under side of the capital and the top of the floor slab below. For beam-and-slab construction the unsupported length of a column shall be taken as the clear distance between the under side of the shallowest beam framing into it and the top of the floor slab below; where beams run in one direction only the clear distance between floor slabs shall be used. For columns supported laterally by struts or beams only, two struts shall be considered an adequate support, provided the angle between the two planes formed by the axis of the column with the axis of each strut is not less than 75 deg. nor more than 105 deg. The unsupported length for this condition shall be considered the clear distance between struts. When haunches are used at the junction of beams or struts with columns, the clear distance between supports may be considered as reduced by two-thirds of the depth of the haunch.

Safe Load on Spiral Columns.

165. The symbols used in Formulas 43 to 50 are defined in Section 107, except as indicated in Sections 165, 167, 170, 172, 180 and 188. The safe axial load on columns reinforced with longitudinal bars and closely spaced spirals enclosing a circular core shall be determined by the following formula:

$$P = A_c f_c + n f_c pA \dots\dots\dots\dots\dots\dots (43)$$

where

A = area of the concrete core enclosed within the spiral;

P = total safe axial load on column whose h/R is less than 40;

p = ratio of effective area of longitudinal reinforcement to area of the concrete core; and

$A_c = A\ (1-p)$ = net area of concrete core.

The allowable value of f_c for use in this type of column shall be determined by the following formula:

$$f_c = 300 + (0.10 + 4p)\,f'_c \dots\dots\dots\dots\dots\dots (44)$$

The longitudinal reinforcement shall consist of at least six bars of minimum diameter of ½ in., and its effective cross-sectional area shall not be less than 1 per cent nor more than 5 per cent of that of the enclosed core.

Spiral Reinforcement.

166. The spiral reinforcement shall be not less in amount than one-fourth the volume of the longitudinal reinforcement. It shall consist of evenly spaced continuous spirals held firmly in place and true to line by at least three vertical spacer bars. The spacing of the spirals shall be not greater than one-sixth of the diameter of the core and in no case more than 3 in. The lateral reinforcement shall meet the requirements of the Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement. (Appendix 7.) Reinforcement shall be protected everywhere by a covering of concrete cast monolithic with the core, which shall have a minimum thickness of 1½ in. in square columns and 2 in. in round or octagonal columns.

Safe Load on Columns with Lateral Ties.

167. The safe axial load on columns reinforced with longitudinal bars and separate lateral ties shall be determined by the following formula:

$$P = A'_c f_c + A_s n f_c \dots\dots\dots\dots\dots\dots (45)$$

where A'_c = net area of concrete in the column (total column area minus steel area); and

A_s = effective cross-sectional area of longitudinal reinforcement.

The value of f_c for this type of column shall not exceed $0.20\,f'_c$. The amount of longitudinal reinforcement considered in the calculations shall be not more than 2 per cent nor less than 0.5 per cent of the total area of the column. The longitudinal reinforcement shall consist of not less than 4 bars of minimum diameter of $\frac{1}{2}$ in., placed with clear distance from the face of the column not less than 2 in.

Lateral Ties.

168. Lateral ties shall be not less than $\frac{1}{4}$ in. in diameter, spaced not farther than 8 in. apart.

Bending Stress in Columns.

169. Reinforced concrete columns subjected to bending stresses shall be treated as follows:

(*a*) *Spiral column.*—The compressive unit stress on the concrete within the core area under combined axial load and bending shall not exceed by more than 20 per cent the value given for axial load by Formula 40.

(*b*) *Columns with Lateral Ties.*—Additional longitudinal reinforcement not to exceed 2 per cent shall be used if required and the compressive unit stress on the concrete under combined axial load and bending may be increased to $0.30\, f'_c$.

Tension due to bending in the longitudinal reinforcement shall not exceed 16,000 lb. per sq. in.

Composite Columns.

170. The safe carrying capacity of composite columns in which a structural steel or cast-iron column is thoroughly encased in a spirally reinforced concrete core shall be based on a certain unit stress for the steel or cast-iron core plus a unit stress of $0.25\, f'_c$ on the area within the spiral core. The unit compressive stress on the steel section shall be determined by the formula:

$$f_r = 18{,}000 - 70\, h/R \qquad \text{(46)}$$

but shall not exceed 16,000 lb. per sq. in. The unit stress on the cast-iron section shall be determined by the formula:

$$f_r = 12{,}000 - 60\, h/R \qquad \text{(47)}$$

but shall not exceed 10,000 lb. per sq. in. In Formulas 46 and 47, f_r = compressive unit stress in metal core, and R = least radius of gyration of the steel or cast-iron section.

The diameter of the cast-iron section shall not exceed one-half of the diameter of the core within the spiral. The spiral reinforcement shall be not less than 0.5 per cent of the volume of the core within the spiral and shall conform in quality, spacing and other requirements to the provisions for spirals in reinforced concrete columns. Ample sections of concrete and continuity of reinforcement shall be provided at the junction with beams or girders. The area of the concrete between the spiral and the metal core shall be not less than that required to carry the total floor load of the story above on the basis of a stress in the concrete of $0.35\, f'_c$, unless special brackets are arranged on the metal core to receive directly the beam or slab loads.

Structural Steel Columns. 171. The safe load on a structural steel column of a section which fully encloses or encases an area of concrete, and which is protected by an outside shell of concrete at least 3 in. thick, shall be computed in the same way as in the columns described in Section 170, allowing 0.25 f'_c on the area of the concrete enclosed by the steel section. The outside shell shall be reinforced by wire mesh or hoops weighing not less than 0.2 lb. per sq. ft. of surface of the core and with a maximum spacing of strands or hoops of 6 in. Special brackets shall be used to receive the entire floor load at each story. The working stress in steel columns shall be calculated by Formula 46, but shall not exceed 16,000 lb. per sq. in.

Long Columns. 172. The permissible working unit stress on the core in axially loaded columns which have a length greater than 40 times the least radius of gyration of the column core (40 R) shall be determined by the formula:

$$\frac{P'}{P} = 1.33 - \frac{h}{120\,R} \quad\ldots\ldots\ldots\ldots\ldots\ldots(48)$$

where P' = total safe axial load on long column;
P = total safe axial load on column of the same section whose h/R is less than 40, determined as in Section 167; and
R = least radius of gyration of column core.

Bending Moments in Columns. 173. The bending moments in interior and exterior columns shall be determined on the basis of loading conditions and end restraint, and shall be provided for in the design.[1] The recognized standard methods shall be followed in calculating the stresses due to combined axial load and bending.

H. Footings.

Types. 174. Various types of reinforced concrete footings are in use depending on conditions. The fundamental principles of the design of reinforced concrete will generally apply to footings as to other structural members. The requirements for flexure and shear in Sections 112 to 139, inclusive, shall govern the design of footings, except as hereinafter provided.

Distribution of Pressure. 175. The upward reaction per unit of area on the footing shall be taken as the column load divided by the area of base of the footing.

Pile Footing. 176. Footings carried on piles shall be treated in the same manner as those bearing directly on the soil, except that the reaction shall be considered as a series of concentrated loads applied at the pile centers.

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[1] The Committee is not prepared to make more definite recommendations at this time.

Sloped Footing. 177. Footings in which the depth has been determined by the requirements for shear as specified in Section 137 may be sloped between the critical section and the edge of the footing, provided that the shear on no section outside the critical section exceeds the value specified, and provided further that the thickness of the footing above the reinforcement at the edge shall not be less than 6 in. for footings on soil nor less than 12 in. for footings on piles.

Stepped Footing. 178. The top of the footing may be stepped instead of sloped, provided that the steps are so placed that the footing will have at all sections a depth at least as great as that required for a sloping top. Stepped footings shall be cast monolithically.

Critical Section for Bending. 179. In a concrete footing which supports a concrete column or pedestal, the critical section for bending shall be taken at the face of the column or pedestal. Where steel or cast-iron bases are used, the moment in the footing shall be calculated at the edge of the base and at the center. In calculating this moment, the column or pedestal load shall be assumed as uniformly distributed over its base.

Square Column on Square Footing. 180. For a square footing supporting a concentric square column, the bending moment at the critical section is that produced by the upward pressure on the trapezoid bounded by one face of the column, the corresponding outside edge of the footing, and the portions of the two diagonals. The center of application of the reaction on the two corner triangles of this trapezoid shall be taken at a distance from the face of the column equal to 0.6 of the projection of the footing. The center of the application of the reaction on the rectangular portion of the trapezoid shall be taken at its center of gravity. This gives a bending moment expressed by the formula:

$$M = \frac{w}{2}(a+1.2\,c)c^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (49)$$

where M = bending moment at critical section of footing;
a = width of face of column or pedestal;
c = projection of footing from face of column; and
w = upward reaction per unit of area of base of footing.

(For typical footing designs, see Figs. 16 to 18.)

Round Column on Square Footing. 181. Square footings supporting a round or octagonal column shall be treated in the same manner as for a square column, using for the distance a the side of a square having an area equal to the area enclosed within the perimeter of the column.

Reinforcement.

182. The reinforcement necessary to resist the bending moment in each direction in the footing shall be determined as for a reinforced concrete beam; the effective depth of the footing shall be the depth from the top to the plane of the reinforcement. The required area of reinforcement thus calculated shall be spaced uniformly across the footing, unless the footing width is greater than the side of the column or pedestal plus twice the effective depth of the footing, in which case the width over which the reinforcement is spread, may be increased to include one-half the remaining width of the footing. In order that no considerable area of the footing shall remain unreinforced, additional bars shall be placed outside of the width specified, but such bars shall not be considered as effective in resisting the calculated bending moment. For the extra bars a spacing double that used for the reinforcement within the effective belt may be used.

Concrete Stress.

183. The extreme fiber stress in compression in the concrete shall be kept within the limits specified in Section 198. The extreme fiber stress in sloped or stepped footings shall be based on the exact shape of the section for a width not greater than that assumed effective for reinforcement.

Irregular Footings.

184. Rectangular or irregular-shaped footings shall be calculated by dividing the footings into rectangles or trapezoids tributary to the sides of the column, using the distance to the actual center of gravity of the area as the moment arm of the upward forces. Outstanding portions of combined footings shall be treated in the same manner. Other portions of combined footings shall be designed as beams or slabs.

Shearing Stresses.

185. See Sections 137 to 139.

Bond Stresses.

186. See Sections 142 to 144.

Transfer of Stress from Column Reinforcement.

187. The compressive stress in longitudinal reinforcement in columns or pedestals shall be transferred to the footing by one of the following methods:

(*a*) By metal distributing bases having a sufficient area and thickness to transmit safely the load from the longitudinal reinforcement in compression and bending. The bases shall be accurately set and provided with a full bearing on the footing.

(*b*) By dowels, at least one for each bar and of total sectional area not less than the area of the longitudinal column reinforcement. The dowels shall project into the columns or into the pedestal or footing a distance not less than 50 times the diameter of the column bars.

Pedestals without Reinforcement.

188. The allowable compressive unit stress on the gross area of a concentrically loaded pedestal without reinforcement shall not exceed 0.25 f'_c. If the column resting on such a pedestal is provided with

distributing bases for the longitudinal reinforcement, the permissible compressive unit stress under the column core shall be determined by the following formula:

$$r_a = 0.25\, f'_c \sqrt[3]{\frac{A}{A'}} \qquad (50)$$

where r_a = permissible working stress over the loaded area;
A = total net area of the top of pedestal; and
A' = loaded area of pedestal.

Pedestals with Reinforcement.

189. Where the permissible load at the top of a pedestal, determined by Formula 50, is less than the column load to be supported, dowels shall be used as specified in Section 187. If the height of the pedestal is not sufficient to give the required embedment to the dowels, they shall extend into the footing to a point 50 diameters below the top of the pedestal for plain bars and 40 diameters for deformed bars. If the column load divided by the cross-section of the pedestal exceeds $0.25\, f'_c$ the pedestal shall be considered as a section of a column and spiral reinforcement shall be provided accordingly.

Permissible Load at Top of Footings.

190. Where distributing bases are used for transferring the stress from column reinforcement directly to the footing, the permissible compressive unit stress shall be determined by Formula 50. This formula may be applied by using A as the area of the top horizontal surface of the footing or with the following modifications:

(*a*) In footings with sloping or stepped top in which a plane, drawn from the edge of the base of the column so that it makes the greatest possible angle with the vertical but remains entirely within the footing, has a slope with the horizontal not greater than 0.5, the total bearing area of the footing may be used for A.

(*b*) In footings in which the slope of the plane referred to is greater than 0.5 but not greater than 2.0, the permissible compressive unit stress at the top shall be determined by direct proportion, in terms of the slope, between the value found for a slope of 0.5 and the value of $0.25\, f'_c$ for a slope of 2.0. For a slope of 2.0 or greater the compressive unit stress at the top shall not exceed $0.25\, f'_c$.

(For typical footing designs, see Figs. 16 and 18.)

Pedestal Footings.

191. Pedestal footings may be designed as pedestals, that is, without reinforcement other than that required to transmit the column load, except that when supported directly on driven piles, a mat of reinforcing bars consisting of not less than 0.20 sq. in. per foot of width in each direction shall be placed 3 in. above the top of the piles. The height of a pedestal footing shall be not greater than 4 times the average width.

I. Reinforced Concrete Retaining Walls.

Types of Retaining Walls.

192. Reinforced concrete retaining walls may be of the following types:

- (*a*) Cantilever;
- (*b*) Counterforted;
- (*c*) Buttressed;
- (*d*) Cellular.

Loads and Unit Stresses.

193. Reinforced concrete retaining walls shall be designed[1] for the loads and reactions, and shall be so proportioned that the permissible unit stresses specified in Sections 196 to 208 are not exceeded. The heels of cantilever, counterforted and buttressed retaining walls shall be proportioned for the maximum resultant vertical loads to which they will be subjected, but the sections shall be such that the normal permissible unit stresses will not be increased by more than 50 per cent when the reaction from the foundation bed is neglected

Details of Design.

194. The following principles shall be followed in the design of reinforced concrete retaining walls:

(*a*) The unsupported toe and heel of the base slabs shall be considered as cantilever beams fixed at the edge of the support.

(*b*) The vertical section of a cantilever wall shall be considered as a cantilever beam fixed at the top of the base.

(*c*) The vertical sections of counterforted and buttressed walls and parts of base slabs supported by the counterforts or buttresses shall be designed in accordance with the requirements specified herein for the continuous slab.

(*d*) The exposed faces of walls without buttresses shall preferably be given a batter of not less than $\frac{1}{4}$ in. in 12 in.

(*e*) Counterforts shall be designed in accordance with the requirements specified for T-beams. Stirrups shall be provided in the counterforts to take the reaction from these spans when the tension reinforcement of the face walls and heels of bases is designed to span between the counterforts. Stirrups shall be anchored as near the exposed faces of the face walls, and as near the lower face of the bases, as practicable.

(*f*) Buttresses shall be designed in accordance with the requirements specified for rectangular beams.

(*g*) The shearing stress at the junction of the base with counterforts or buttresses shall not exceed the values specified in Sections 120 to 135.

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[1] In proportioning retaining walls consideration shall be given to the following:

(*a*) Maximum bearing pressure of soil;

(*b*) Uniformity of distribution of foundation pressure on yielding soils;

(*c*) Stability against sliding;

(*d*) Minor increase of the horizontal forces may seriously affect (*a*) and (*b*).

(*h*) Horizontal metal reinforcement shall be well distributed and of such form as to develop a high bond resistance. At least 0.25 sq. in. of horizontal metal reinforcement for each foot of height shall be provided near exposed surfaces not otherwise reinforced, to resist the formation of temperature and shrinkage cracks.

(*i*) Provision for temperature changes shall be made by grooved lock joints spaced not over 60 ft. apart.

(*j*) Counterforts and buttresses, where used, shall be located under all points of concentrated loading, and at intermediate points spaced 8 to 12 ft. apart.

(*k*) The walls shall be cast monolithically between expansion joints, unless construction joints made in accordance with Sections 69 and 73 are provided.

Drains. 195. Drains or "weep holes" not less than 4 in. in diameter and not more than 10 ft. apart, shall be provided. In counterforted walls there shall be at least one drain for each pocket formed by the counterforts.

J. Floor Slabs Supported on Four Sides.[1]

K. Shrinkage and Temperature Stresses.[1]

L. Summary of Working Stresses.

Notation. 196. f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Appendix 14) and the Tentative Methods of Making Compression Tests of Concrete (Appendix 13).

a. Maximum Direct Stresses in Concrete.

Direct Compression. 197. (*a*) Columns whose length does not exceed 40 *R:*

(1) With spirals.................. varies with amount of longitudinal reinforcement

(2) Without spirals.............................. $0.20 f'_c$

(*b*) Long columns.............................. see Section 172

(*c*) Piers and Pedestals:

(1) Without reinforcement...................... $0.25 f'_c$

(2) Special cases.......................... see Section 188

Compression in Extreme Fiber. 198. (*a*) Extreme fiber stress in flexure.................... $0.40 f'_c$

(*b*) Extreme fiber stress adjacent to supports of continuous beams .... $0.45 f'_c$

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[1] The Committee is not now ready to report on these subjects.

Bearing Compression.

199. Anchorage of reinforcement .... 0.50 f'_c

Tension.

200. All concrete members .... none

b. Maximum Shearing Stresses in Concrete.

Beams without Web Reinforcement.

201. (*a*) Longitudinal bars anchored .... 0.03 f'_c
  (*b*) Longitudinal bars not anchored .... 0.02 f'_c

Beams with Reinforcement.

202. (*a*) Beams with stirrups .... see Sections 125 and 128
  (*b*) Beams with bars bent up in several planes . . see Section 125
  (*c*) Beams with bars bent up in a single plane:
    (1) Longitudinal bars anchored .... 0.12 f'_c
    (2) Longitudinal bars not anchored .... 0.06 f'_c

Flat Slabs.

203. (*a*) Shear at distance *d* from capital or dropped panel . . . 0.03 f'_c
  (*b*) Other limiting cases in flat slabs .... see Section 136

Footings.

204. (*a*) Longitudinal bars anchored .... 0.03 f'
  (*b*) Longitudinal bars not anchored .... 0.02 f'

c. Maximum Stresses in Reinforcement.

Tension in Steel.

205. (*a*) Billet-steel bars:
    (1) Structural steel grade .... 16,000 lb. per sq. in.
    (2) Intermediate grade .... 18,000 " "
    (3) Hard grade .... 18,000 " "
  (*b*) Rail-steel bars .... 16,000 " "
  (*c*) Structural steel .... 16,000 " "
  (*d*) Cold-drawn steel wire:
    (1) Spirals .... stress not calculated
    (2) Elsewhere .... 18,000 lb. per sq. in.

Compression in Steel.

206. (*a*) Bars .... same as Section 205 (*a*) and (*b*)
  (*b*) Structural steel core of composite column . . 18,000 lb. per sq. in., reduced for slenderness ratio
  (*c*) Structural steel column .... 16,000 lb. per sq. in., reduced for slenderness ratio

Compression in Cast Iron.

207. Composite columns with spirals .... 10,000 lb. per sq. in.

d. Maximum Bond between Concrete and Steel.

Bond.

208. (*a*) Beams and slabs, plain bars .... 0.04 f'_c
  (*b*) Beams and slabs, deformed bars .... 0.05 f'_c
  (*c*) Footings, plain bars, one-way .... 0.04 f'_c
  (*d*) Footings, deformed bars, one-way .... 0.05 f'_c
  (*e*) Footings, two-way reinforcement ...... (*c*) or (*d*) reduced by 25 per cent
  (*f*) Footings, each additional direction of reinforcement .... (*c*) or (*d*) reduced by 10 per cent.

TABLE IV.—PROPORTIONS[1] FOR CONCRETE OF GIVEN COMPRESSIVE STRENGTH AT 28 DAYS.

The table gives the proportions in which Portland cement and a wide range in sizes of fine and coarse aggregates should be mixed to obtain concrete of compressive strengths ranging from 1500 to 3000 lb. per sq. in. at 28 days. Proportions are given for concrete of four different consistencies.

The purpose of the table is twofold:

(1) To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

(2) To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

If the proportions to be used in the work are selected from the table without preliminary tests of the materials, and control tests are not made during the progress of the work, the mixtures in bold-face type shall be used.

The use of this table as a guide in the selection of concrete mixtures is based on the following:

(1) Concrete shall be plastic;

(2) Aggregates shall be clean and structurally sound;

(3) Aggregates shall be graded between the sizes indicated;

(4) Cement shall conform to the requirements of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9–21) of the American Society for Testing Materials. (Appendix 3.)

The plasticity of the concrete shall be determined by the slump test carried out in accordance with the Tentative Specifications for Workability of Concrete for Concrete Pavements (Serial Designation: D 62–20 T) of the American Society for Testing Materials. (Appendix 12.)

Apply the following rules in determining the size assigned to a given aggregate:

(1) Not less than 15 per cent shall be retained between the sieve which is considered the maximum size[2] and the next smaller sieve.

(2) Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size.[2]

(3) Only the sieve sizes given in the table shall be considered in applying rules (1) and (2).

(4) Sieve analysis shall be made in accordance with the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41–21 T) of the American Society for Testing Materials. (Appendix 9.)

Proportions may be interpolated for concrete strengths, aggregate sizes and consistencies not covered by the table or determined by test.

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[1] Based on the 28-day compressive strengths of 6 by 12-in. cylinders, made and stored in accordance with the Tentative Methods of Making Compression Tests of Concrete (Serial Designation: C 39-21 T) of the American Society for Testing Materials. (Appendix 13.)

[2] For example: a graded sand with 16 per cent retained on the No. 8 sieve would fall in the 0-No. 4 size; if 14 per cent or less were retained, the sand would fall in the 0-No. 8 size. A coarse aggregate having 16 per cent coarser than 2-in. sieve would be considered as 3-in. aggregate.

TABLE IV. (*Continued*).—PROPORTIONS FOR 1500 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of Portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
			0 – No. 14	0 – No. 8	0 – No. 4	0 – ⅜ in.
None	½ to 1	1 : 2.8	1 : 3.2	1 : 3.8	1 : 4.4	1 : 5.1
	3 " 4	1 : 2.4	1 : 2.8	1 : 3.3	1 : 3.8	1 : 4.5
	6 " 7	**1 : 1.9**	**1 : 2.2**	**1 : 2.6**	**1 : 3.0**	**1 : 3.6**
	8 " 10	1 : 1.4	1 : 1.6	1 : 1.8	1 : 2.1	1 : 2.5
No. 4 to ¾ in.	½ to 1	1 : 2.6 : 4.6	1 : 2.9 : 4.3	1 : 3.4 : 4.1	1 : 3.9 : 3.6	1 : 4.6 : 3.1
	3 " 4	1 : 2.3 : 4.0	1 : 2.6 : 3.8	1 : 2.9 : 3.6	1 : 3.4 : 3.2	1 : 4.1 : 2.8
	6 " 7	**1 : 1.8 : 3.4**	**1 : 2.0 : 3.2**	**1 : 2.3 : 3.1**	**1 : 2.6 : 2.8**	**1 : 3.1 : 2.5**
	8 " 10	1 : 1.1 : 2.5	1 : 1.3 : 2.4	1 : 1.5 : 2.4	1 : 1.7 : 2.2	1 : 2.1 : 2.0
No. 4 to 1 in.	½ to 1	1 : 2.4 : 5.3	1 : 2.7 : 5.2	1 : 3.1 : 5.0	1 : 3.5 : 4.7	1 : 4.3 : 4.3
	3 " 4	1 : 2.1 : 4.7	1 : 2.4 : 4.5	1 : 2.7 : 4.4	1 : 3.1 : 4.1	1 : 3.7 : 3.7
	6 " 7	**1 : 1.6 : 3.9**	**1 : 1.8 : 3.8**	**1 : 2.1 : 3.7**	**1 : 2.4 : 3.5**	**1 : 2.9 : 3.3**
	8 " 10	1 : 1.1 : 2.9	1 : 1.2 : 2.8	1 : 1.4 : 2.8	1 : 1.6 : 2.7	1 : 1.9 : 2.5
No. 4 to 1½ in.	½ to 1	1 : 2.4 : 6.0	1 : 2.7 : 5.9	1 : 3.1 : 5.8	1 : 3.5 : 5.4	1 : 4.1 : 5.1
	3 " 4	1 : 2.0 : 5.4	1 : 2.3 : 5.3	1 : 2.7 : 5.2	1 : 3.0 : 5.0	1 : 3.5 : 4.6
	6 " 7	**1 : 1.6 : 4.4**	**1 : 1.8 : 4.3**	**1 : 2.0 : 4.3**	**1 : 2.3 : 4.1**	**1 : 2.7 : 3.9**
	8 " 10	1 : 1.0 : 3.3	1 : 1.1 : 3.2	1 : 1.3 : 3.2	1 : 1.5 : 3.1	1 : 1.8 : 2.9
No. 4 to 2 in.	½ to 1	1 : 2.2 : 6.9	1 : 2.4 : 6.8	1 : 2.8 : 6.8	1 : 3.1 : 6.6	1 : 3.7 : 6.4
	3 " 4	1 : 1.8 : 6.2	1 : 2.0 : 6.1	1 : 2.4 : 6.1	1 : 2.7 : 6.0	1 : 3.1 : 5.7
	6 " 7	**1 : 1.4 : 5.1**	**1 : 1.6 : 5.0**	**1 : 1.8 : 5.0**	**1 : 2.0 : 5.0**	**1 : 2.4 : 4.8**
	8 " 10	1 : 0.9 : 3.8	1 : 1.0 : 3.8	1 : 1.1 : 3.8	1 : 1.3 : 3.8	1 : 1.5 : 3.7
⅜ to 1 in.	½ to 1	1 : 2.8 : 5.2	1 : 3.1 : 5.1	1 : 3.6 : 4.8	1 : 4.2 : 4.6	1 : 4.8 : 4.1
	3 " 4	1 : 2.4 : 4.5	1 : 2.6 : 4.5	1 : 3.1 : 4.3	1 : 3.6 : 4.0	1 : 4.1 : 3.6
	6 " 7	**1 : 1.9 : 3.9**	**1 : 2.1 : 3.7**	**1 : 2.4 : 3.6**	**1 : 2.8 : 3.4**	**1 : 3.2 : 3.1**
	8 " 10	1 : 1.3 : 2.8	1 : 1.4 : 2.8	1 : 1.6 : 2.7	1 : 1.9 : 2.6	1 : 2.2 : 2.4
⅜ to 1½ in.	½ to 1	1 : 2.8 : 5.8	1 : 3.1 : 5.7	1 : 3.5 : 5.5	1 : 4.1 : 5.3	1 : 4.7 : 4.9
	3 " 4	1 : 2.4 : 5.2	1 : 2.7 : 5.1	1 : 3.1 : 5.0	1 : 3.5 : 4.8	1 : 4.1 : 4.4
	6 " 7	**1 : 1.9 : 4.3**	**1 : 2.1 : 4.2**	**1 : 2.4 : 4.2**	**1 : 2.7 : 4.0**	**1 : 3.1 : 3.7**
	8 " 10	1 : 1.2 : 3.2	1 : 1.4 : 3.2	1 : 1.6 : 3.1	1 : 1.8 : 3.0	1 : 2.1 : 2.9
⅜ to 2 in.	½ to 1	1 : 2.7 : 6.6	1 : 3.0 : 6.6	1 : 3.4 : 6.5	1 : 3.9 : 6.4	1 : 4.4 : 6.0
	3 " 4	1 : 2.3 : 5.9	1 : 2.6 : 5.9	1 : 2.9 : 5.8	1 : 3.3 : 5.6	1 : 3.7 : 5.5
	6 " 7	**1 : 1.8 : 4.9**	**1 : 2.0 : 4.8**	**1 : 2.2 : 4.8**	**1 : 2.6 : 4.8**	**1 : 3.0 : 4.5**
	8 " 10	1 : 1.2 : 3.7	1 : 1.3 : 3.7	1 : 1.5 : 3.7	1 : 1.7 : 3.6	1 : 1.9 : 3.5
¾ to 1½ in.	½ to 1	1 : 3.2 : 5.4	1 : 3.6 : 5.3	1 : 4.1 : 5.1	1 : 4.7 : 4.8	1 : 5.3 : 4.4
	3 " 4	1 : 2.8 : 4.8	1 : 3.2 : 4.8	1 : 3.6 : 4.6	1 : 4.0 : 4.4	1 : 4.6 : 4.0
	6 " 7	**1 : 2.1 : 4.0**	**1 : 2.5 : 4.0**	**1 : 2.8 : 3.9**	**1 : 3.2 : 3.7**	**1 : 3.5 : 3.4**
	8 " 10	1 : 1.5 : 3.0	1 : 1.7 : 3.0	1 : 1.9 : 2.9	1 : 2.2 : 2.8	1 : 2.5 : 2.7
¾ to 2 in.	½ to 1	1 : 3.2 : 6.2	1 : 3.6 : 6.1	1 : 4.0 : 6.0	1 : 4.6 : 5.8	1 : 5.2 : 5.4
	3 " 4	1 : 2.8 : 5.5	1 : 3.1 : 5.5	1 : 3.5 : 5.4	1 : 3.9 : 5.2	1 : 4.5 : 4.9
	6 " 7	**1 : 2.1 : 4.5**	**1 : 2.4 : 4.6**	**1 : 2.7 : 4.5**	**1 : 3.1 : 4.4**	**1 : 3.5 : 4.1**
	8 " 10	1 : 1.4 : 3.4	1 : 1.6 : 3.4	1 : 1.8 : 3.4	1 : 2.1 : 3.4	1 : 2.4 : 3.3
¾ to 3 in.	½ to 1	1 : 3.2 : 7.1	1 : 3.6 : 7.1	1 : 4.0 : 7.0	1 : 4.6 : 6.9	1 : 5.2 : 6.6
	3 " 4	1 : 2.7 : 6.3	1 : 3.0 : 6.3	1 : 3.4 : 6.3	1 : 4.0 : 6.2	1 : 4.5 : 5.9
	6 " 7	**1 : 2.1 : 5.1**	**1 : 2.4 : 5.2**	**1 : 2.7 : 5.2**	**1 : 3.1 : 6.1**	**1 : 3.5 : 4.9**
	8 " 10	1 : 1.4 : 3.8	1 : 1.6 : 3.9	1 : 1.8 : 3.9	1 : 2.1 : 3.9	1 : 2.4 : 3.8

Table IV. (*Continued*).—Proportions for 2000 lb. per sq. in. Concrete.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of Portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
		0 – No. 28	0 – No. 14	0 – No. 8	0 – No. 4	0 – ⅜ in.
None	½ to 1	1 : 2.2	1 : 2.6	1 : 3.0	1 : 3.5	1 : 4.1
	3 " 4	1 : 1.9	1 : 2.2	1 : 2.6	1 : 3.0	1 : 3.5
	6 " 7	**1 : 1.5**	**1 : 1.7**	**1 : 2.0**	**1 : 2.3**	**1 : 2.7**
	8 " 10	**1 : 1.0**	**1 : 1.1**	**1 : 1.3**	1 : 1.6	1 : 1.8
No. 4 to ¾ in.	½ to 1	1 : 2.1 : 3.8	1 : 2.3 : 3.7	1 : 2.6 : 3.5	1 : 3.0 : 3.1	1 : 3.6 : 2.8
	3 " 4	1 : 1.7 : 3.3	1 : 1.9 : 3.2	1 : 2.2 : 3.1	1 : 2.6 : 2.8	1 : 3.0 : 2.4
	6 " 7	**1 : 1.3 : 2.7**	**1 : 1.4 : 2.6**	**1 : 1.7 : 2.5**	**1 : 1.9 : 2.3**	**1 : 2.3 : 2.1**
	8 " 10	1 : 0.8 : 1.9	1 : 0.9 : 1.9	1 : 1.0 : 1.8	1 : 1.2 : 1.7	1 : 1.5 : 1.6
No. 4 to 1 in.	½ to 1	1 : 1.9 : 4.5	1 : 2.2 : 4.3	1 : 2.5 : 4.2	1 : 2.8 : 3.9	1 : 3.4 : 3.6
	3 " 4	1 : 1.6 : 3.9	1 : 1.8 : 3.8	1 : 2.1 : 3.7	1 : 2.4 : 3.5	1 : 2.8 : 3.2
	6 " 7	**1 : 1.2 : 3.1**	**1 : 1.3 : 3.1**	**1 : 1.5 : 3.0**	**1 : 1.8 : 2.9**	**1 : 2.1 : 2.7**
	8 " 10	1 : 0.7 : 2.2	1 : 0.8 : 2.2	1 : 1.0 : 2.3	1 : 1.1 : 2.1	1 : 1.3 : 2.0
No. 4 to 1½ in.	½ to 1	1 : 1.9 : 5.0	1 : 2.1 : 4.9	1 : 2.4 : 4.9	1 : 2.7 : 4.6	1 : 3.2 : 4.4
	3 " 4	1 : 1.6 : 4.4	1 : 1.7 : 4.3	1 : 2.0 : 4.2	1 : 2.4 : 4.0	1 : 2.7 : 3.8
	6 " 7	**1 : 1.1 : 3.5**	**1 : 1.3 : 3.5**	**1 : 1.4 : 3.5**	**1 : 1.7 : 3.4**	**1 : 2.0 : 3.2**
	8 " 10	1 : 0.7 : 2.5	1 : 0.8 : 2.5	1 : 0.9 : 2.5	1 : 1.0 : 2.4	1 : 1.2 : 2.3
No. 4 to 2 in.	½ to 1	1 : 1.7 : 5.8	1 : 1.9 : 5.7	1 : 2.1 : 5.8	1 : 2.4 : 5.6	1 : 2.8 : 5.5
	3 " 4	1 : 1.4 : 5.0	1 : 1.5 : 5.0	1 : 1.8 : 5.0	1 : 2.0 : 4.9	1 : 2.3 : 4.7
	6 " 7	**1 : 1.0 : 4.1**	**1 : 1.1 : 4.1**	**1 : 1.2 : 4.1**	**1 : 1.4 : 4.1**	**1 : 1.7 : 3.9**
	8 " 10	1 : 0.6 : 2.9	1 : 0.7 : 2.9	1 : 0.7 : 3.0	1 : 0.8 : 2.9	1 : 1.0 : 2.9
⅜ to 1 in.	½ to 1	1 : 2.2 : 4.4	1 : 2.5 : 4.2	1 : 2.8 : 4.1	1 : 3.3 : 3.8	1 : 3.8 : 3.4
	3 " 4	1 : 1.9 : 3.8	1 : 2.1 : 3.7	1 : 2.4 : 3.6	1 : 2.8 : 3.4	1 : 3.2 : 3.1
	6 " 7	**1 : 1.4 : 3.1**	**1 : 1.5 : 3.0**	**1 : 1.8 : 3.0**	**1 : 2.1 : 2.8**	**1 : 2.4 : 2.5**
	8 " 10	1 : 0.9 : 2.2	1 : 1.0 : 2.2	1 : 1.1 : 2.2	1 : 1.3 : 2.0	1 : 1.5 : 1.9
⅜ to 1½ in.	½ to 1	1 : 2.2 : 4.9	1 : 2.5 : 4.8	1 : 2.8 : 4.7	1 : 3.2 : 4.6	1 : 3.7 : 4.2
	3 " 4	1 : 1.9 : 4.3	1 : 2.1 : 4.2	1 : 2.4 : 4.1	1 : 2.7 : 4.0	1 : 3.1 : 3.7
	6 " 7	**1 : 1.4 : 3.5**	**1 : 1.5 : 3.4**	**1 : 1.7 : 3.4**	**1 : 2.0 : 3.3**	**1 : 2.3 : 3.1**
	8 " 10	1 : 0.9 : 2.5	1 : 1.0 : 2.5	1 : 1.1 : 2.4	1 : 1.3 : 2.4	1 : 1.5 : 2.3
⅜ to 2 in.	½ to 1	1 : 2.1 : 5.6	1 : 2.3 : 5.5	1 : 2.6 : 5.5	1 : 3.0 : 5.4	1 : 3.5 : 5.1
	3 " 4	1 : 1.7 : 4.8	1 : 2.0 : 4.8	1 : 2.2 : 4.8	1 : 2.5 : 4.7	1 : 2.9 : 4.4
	6 " 7	**1 : 1.3 : 4.0**	**1 : 1.4 : 3.9**	**1 : 1.6 : 3.9**	**1 : 1.8 : 3.9**	**1 : 2.1 : 3.8**
	8 " 10	1 : 0.8 : 2.9	1 : 0.9 : 2.9	1 : 1.0 : 2.9	1 : 1.2 : 2.9	1 : 1.3 : 2.8
¾ to 1½ in.	½ to 1	1 : 2.6 : 4.5	1 : 2.9 : 4.5	1 : 3.3 : 4.4	1 : 3.8 : 4.2	1 : 4.3 : 3.9
	3 " 4	1 : 2.2 : 3.9	1 : 2.5 : 3.9	1 : 2.8 : 3.8	1 : 3.2 : 3.6	1 : 3.6 : 3.3
	6 " 7	**1 : 1.6 : 3.2**	**1 : 1.8 : 3.2**	**1 : 2.1 : 3.1**	**1 : 2.4 : 3.0**	**1 : 2.7 : 2.8**
	8 " 10	1 : 1.0 : 2.3	1 : 1.2 : 2.3	1 : 1.4 : 2.2	1 : 1.6 : 2.2	1 : 1.8 : 2.1
¾ to 2 in.	½ to 1	1 : 2.5 : 5.2	1 : 2.8 : 5.2	1 : 3.2 : 5.1	1 : 3.6 : 5.0	1 : 4.1 : 4.7
	3 " 4	1 : 2.1 : 4.5	1 : 2.4 : 4.5	1 : 2.7 : 4.4	1 : 3.1 : 4.3	1 : 3.5 : 4.0
	6 " 7	**1 : 1.6 : 3.7**	**1 : 1.8 : 3.7**	**1 : 2.0 : 3.7**	**1 : 2.3 : 3.6**	**1 : 2.6 : 3.5**
	8 " 10	1 : 1.0 : 2.6	1 : 1.1 : 2.7	1 : 1.3 : 2.6	1 : 1.5 : 2.7	1 : 1.7 : 2.6
¾ to 3 in.	½ to 1	1 : 2.5 : 6.0	1 : 2.9 : 5.9	1 : 3.2 : 5.9	1 : 3.6 : 5.8	1 : 4.1 : 5.6
	3 " 4	1 : 2.1 : 5.1	1 : 2.4 : 5.2	1 : 2.7 : 5.2	1 : 3.1 : 5.1	1 : 3.5 : 4.9
	6 " 7	**1 : 1.5 : 4.1**	**1 : 1.7 : 4.2**	**1 : 2.0 : 4.2**	**1 : 2.3 : 4.2**	**1 : 2.5 : 4.0**
	8 " 10	1 : 1.0 : 2.9	1 : 1.1 : 3.0	1 : 1.3 : 3.0	1 : 1.5 : 3.0	1 : 1.7 : 3.0

TABLE IV. (*Continued*).—PROPORTIONS FOR 2500 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of Portland Cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
		0 – No. 28	0 – No. 14	0 – No. 8	0 – No. 4	0 – ⅜ in.
None	½ to 1	1 : 1.8	1 : 2.1	1 : 2.4	1 : 2.9	1 : 3.3
	3 " 4	1 : 1.5	1 : 1.8	1 : 2.1	1 : 2.4	1 : 2.8
	6 " 7	**1 : 1.1**	**1 : 1.3**	**1 : 1.6**	**1 : 1.8**	**1 : 2.1**
	8 " 10	1 : 0.7	1 : 0.8	1 : 0.9	1 : 1.1	1 : 1.3
No. 4 to ¾ in.	½ to 1	1 : 1.6 : 3.2	1 : 1.8 : 3.1	1 : 2.1 : 3.0	1 : 2.4 : 2.7	1 : 2.9 : 2.4
	3 " 4	1 : 1.3 : 2.8	1 : 1.5 : 2.7	1 : 1.7 : 2.6	1 : 2.0 : 2.4	1 : 2.4 : 2.2
	6 " 7	**1 : 1.0 : 2.2**	**1 : 1.1 : 2.2**	**1 : 1.3 : 2.1**	**1 : 1.5 : 2.0**	**1 : 1.8 : 1.8**
	8 " 10	1 : 0.5 : 1.4	1 : 0.6 : 1.4	1 : 0.7 : 1.4	1 : 0.8 : 1.4	1 : 1.0 : 1.3
No. 4 to 1 in.	½ to 1	1 : 1.5 : 3.7	1 : 1.7 : 3.7	1 : 2.0 : 3.5	1 : 2.2 : 3.4	1 : 2.7 : 3.1
	3 " 4	1 : 1.2 : 3.3	1 : 1.4 : 3.2	1 : 1.6 : 3.1	1 : 1.9 : 3.0	1 : 2.2 : 2.7
	6 " 7	**1 : 0.9 : 2.6**	**1 : 1.0 : 2.5**	**1 : 1.1 : 2.5**	**1 : 1.3 : 2.4**	**1 : 1.6 : 2.3**
	8 " 10	1 : 0.5 : 1.7	1 : 0.6 : 1.7	1 : 0.6 : 1.7	1 : 0.7 : 1.6	1 : 0.9 : 1.5
No. 4 to 1½ in.	½ to 1	1 : 1.4 : 4.2	1 : 1.6 : 4.1	1 : 1.9 : 4.1	1 : 2.2 : 4.0	1 : 2.5 : 3.8
	3 " 4	1 : 1.2 : 3.7	1 : 1.3 : 3.6	1 : 1.5 : 3.6	1 : 1.8 : 3.5	1 : 2.1 : 3.3
	6 " 7	**1 : 0.9 : 2.9**	**1 : 0.9 : 2.8**	**1 : 1.1 : 2.8**	**1 : 1.3 : 2.8**	**1 : 1.5 : 2.6**
	8 " 10	1 : 0.5 : 1.9	1 : 0.5 : 1.9	1 : 0.6 : 1.9	1 · 0.7 : 1.8	1 : 0.8 : 1.8
No. 4 to 2 in.	½ to 1	1 : 1.3 : 4.9	1 : 1.4 : 4.8	1 : 1.6 : 4.9	1 : 1.9 : 4.8	1 : 2.2 : 4.7
	3 " 4	1 : 1.1 : 4.3	1 : 1.2 : 4.2	1 : 1.3 : 4.3	1 : 1.6 : 4.2	1 : 1.8 : 4.1
	6 " 7	**1 : 0.7 : 3.3**	**1 : 0.8 : 3.3**	**1 : 0.9 : 3.4**	**1 1.1 : 3.3**	**1 : 1.2 : 3.3**
	8 " 10	1 : 0.4 : 2.2	1 : 2.4 : 2.2	1 : 0.5 : 2.2	1 : 0.6 : 2.2	1 : 0.6 : 2.2
⅜ to 1 in.	½ to 1	1 : 1.8 : 3.7	1 : 2.0 : 3.6	1 : 2.3 : 3.5	1 : 2.6 : 3.3	1 : 3.0 : 2.9
	3 " 4	1 : 1.4 : 3.2	1 : 1.6 : 3.1	1 : 1.9 : 2.9	1 : 2.2 : 2.9	1 : 2.5 : 2.6
	6 " 7	**1 : 1.0 : 2.5**	**1 : 1.2 : 2.5**	**1 : 1.3 : 2.4**	**1 : 1.6 : 2.3**	**1 : 1.8 : 2.2**
	8 " 10	1 : 0.6 : 1.6	1 : 0.7 : 1.6	1 : 0.8 : 1.6	1 : 0.9 : 1.6	1 : 1.0 : 1.5
⅜ to 1½ in.	½ to 1	1 : 1.7 : 4.1	1 : 1.9 : 4.1	1 : 2.2 : 4.0	1 : 2.5 : 3.9	1 : 2.9 : 3.6
	3 " 4	1 : 1.5 : 3.6	1 : 1.6 : 3.6	1 : 1.8 : 3.5	1 : 2.1 : 3.4	1 : 2.3 : 3.2
	6 " 7	**1 : 1.0 : 2.9**	**1 : 1.2 : 2.8**	**1 : 1.3 : 2.8**	**1 : 1.5 : 2.7**	**1 : 1.8 : 2.6**
	8 " 10	1 : 0.6 : 1.9	1 : 0.6 : 1.9	1 : 0.8 : 1.8	1 : 0.9 : 1.8	1 : 1.0 : 1.8
⅜ to 2 in.	½ to 1	1 : 1.7 : 4.7	1 : 1.8 : 4.7	1 : 2.1 : 4.7	1 : 2.4 : 4.6	1 : 2.7 : 4.4
	3 " 4	1 : 1.4 : 4.1	1 : 1.5 : 4.1	1 : 1.7 : 4.1	1 : 2.0 : 4.0	1 : 2.3 : 3.9
	6 " 7	**1 : 1.0 : 3.2**	**1 : 1.1 : 3.2**	**1 : 1.2 : 3.2**	**1 : 1.4 : 3.2**	**1 : 1.6 : 3.1**
	8 " 10	1 : 0.5 : 2.1	1 : 0.6 : 2.1	1 : 0.7 : 2.2	1 : 0.8 : 2.2	1 : 0.9 : 2.1
¾ to 1½ in.	½ to 1	1 : 2.0 : 3.8	1 : 2.3 : 3.8	1 : 2.6 : 3.7	1 : 3.0 : 3.6	1 : 3.4 : 3.3
	3 " 4	1 : 1.7 : 3.3	1 : 2.0 : 3.3	1 : 2.2 : 3.2	1 : 2.5 : 3.2	1 : 2.9 : 2.9
	6 " 7	**1 : 1.2 : 2.6**	**1 : 1.4 : 2.6**	**1 : 1.6 : 2.6**	**1 : 1.9 : 2.5**	**1 : 2.1 : 2.3**
	8 " 10	1 : 0.7 : 1.7	1 : 0.8 : 1.7	1 : 0.9 : 1.7	1 : 1.1 : 1.7	1 : 1.2 : 1.6
¾ to 2 in.	½ to 1	1 : 2.0 : 4.4	1 : 2.2 : 4.4	1 : 2.5 : 4.3	1 : 2.9 : 4.3	1 : 3.3 : 4.1
	3 " 4	1 : 1.7 : 3.8	1 : 1.9 : 3.8	1 : 2.1 : 3.8	1 : 2.5 : 3.7	1 : 2.8 : 3.6
	6 " 7	**1 : 1.2 : 3.0**	**1 : 1.4 : 3.0**	**1 : 1.5 : 3.0**	**1 : 1.8 : 3.0**	**1 : 2.0 : 2.8**
	8 " 10	1 : 0.7 : 2.0	1 : 0.8 : 2.0	1 : 0.9 : 2.0	1 : 1.0 : 2.0	1 : 1.2 : 2.0
¾ to 3 in.	½ to 1	1 : 2.0 : 5.0	1 : 2.2 : 5.0	1 : 2.5 : 5.0	1 : 2.7 : 5.0	1 : 3.2 : 4.7
	3 " 4	1 : 1.7 : 4.3	1 : 1.9 : 4.3	1 : 2.1 : 4.3	1 : 2.4 : 4.3	1 : 2.7 : 4.1
	6 " 7	**1 : 1.2 : 3.3**	**1 : 1.4 : 3.4**	**1 : 1.5 : 3.4**	**1 : 1.8 : 3.4**	**1 : 2.0 : 3.3**
	8 " 10	1 : 0.7 : 2.2	1 : 0.8 : 2.2	1 : 0.9 : 2.2	1 : 1.0 : 2.3	1 : 1.2 : 2.3

TABLE IV. (*Continued*).—PROPORTIONS FOR 3000 LB. PER SQ. IN. CONCRETE.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1 : 2.6 : 4.6 indicates 1 part by volume of Portland Cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate.	Slump, in.	Size of Fine Aggregate.				
		0 – No. 28	0 – No. 14	0 – No. 8	0 – No. 4	0 – ⅜ in.
None	½ to 1	1 : 1.5	1 : 1.7	1 : 2.0	1 : 2.3	1 : 2.7
	3 " 4	1 : 1.2	1 : 1.4	1 : 1.7	1 : 1.9	1 : 2.3
	6 " 7	**1 : 0.9**	**1 : 1.0**	**1 : 1.2**	**1 : 1.4**	**1 : 1.6**
	8 " 10	1 : 0.5	1 : 0.6	1 : 0.7	1 : 0.8	1 : 0.9
No. 4 to ¾ in.	½ to 1	1 : 1.3 : 2.7	1 : 1.5 : 2.6	1 : 1.7 : 2.5	1 : 1.9 : 2.4	1 : 2.3 : 2.1
	3 " 4	1 : 1.0 : 2.3	1 : 1.2 : 2.2	1 : 1.4 : 2.2	1 : 1.6 : 2.0	1 : 1.9 : 1.8
	6 " 7	**1 : 0.7 : 1.7**	**1 : 0.8 : 1.7**	**1 : 0.9 : 1.7**	**1 : 1.1 : 1.6**	**1 : 1.3 : 1.4**
	8 " 10	1 : 0.3 : 1.0	1 : 0.4 : 1.0	1 : 0.5 : 1.0	1 : 0.5 : 1.0	1 : 0.6 : 0.9
No. 4 to 1 in.	½ to 1	1 : 1.2 : 3.1	1 : 1.3 : 3.1	1 : 1.5 : 3.0	1 : 1.8 : 2.9	1 : 2.1 : 2.7
	3 " 4	1 : 0.9 : 2.7	1 : 1.1 : 2.6	1 : 1.2 : 2.6	1 : 1.4 : 2.5	1 : 1.7 : 2.3
	6 " 7	**1 : 0.6 : 2.0**	**1 : 0.7 : 2.0**	**1 : 0.8 : 2.0**	**1 : 0.9 : 1.9**	**1 : 1.1 : 1.8**
	8 " 10	1 : 0.3 : 1.2	1 : 0.3 : 1.2	1 : 0.4 : 1.2	1 : 0.5 : 1.2	1 : 0.6 : 1.2
No. 4 to 1½ in.	½ to 1	1 : 1.1 : 3.6	1 : 1.2 : 3.5	1 : 1.5 : 3.5	1 : 1.7 : 3.4	1 : 2.0 : 3.2
	3 " 4	1 : 0.9 : 3.0	1 : 1.0 : 2.9	1 : 1.2 : 2.9	1 : 1.4 : 2.9	1 : 1.6 : 2.7
	6 " 7	**1 : 0.6 : 2.2**	**1 : 0.7 : 2.2**	**1 : 0.8 : 2.2**	**1 : 0.9 : 2.2**	**1 : 1.1 : 2.1**
	8 " 10	1 : 0.3 : 1.4	1 : 0.3 : 1.3	1 : 0.4 : 1.4	1 : 0.5 : 1.4	1 : 0.5 : 1.3
No. 4 to 2 in.	½ to 1	1 : 1.0 : 4.1	1 : 1.1 : 4.1	1 : 1.2 : 4.1	1 : 1.4 : 4.1	1 : 1.6 : 4.0
	3 " 4	1 : 0.8 : 3.4	1 : 0.9 : 3.4	1 : 1.0 : 3.5	1 : 1.1 : 3.4	1 : 1.3 : 3.4
	6 " 7	**1 : 0.5 : 2.6**	**1 : 0.6 : 2.6**	**1 : 0.6 : 2.7**	**1 : 0.7 : 2.6**	**1 : 0.9 : 2.6**
	8 " 10	1 : 0.2 : 1.6	1 : 0.3 : 1.6	1 : 0.3 : 1.7	1 : 0.4 : 1.7	1 : 0.4 : 1.7
⅜ to 1 in.	½ to 1	1 : 1.4 : 3.1	1 : 1.5 : 3.0	1 : 1.8 : 2.9	1 : 2.1 : 2.8	1 : 2.4 : 2.6
	3 " 4	1 : 1.1 : 2.6	1 : 1.3 : 2.6	1 : 1.5 : 2.5	1 : 1.7 : 2.4	1 : 2.0 : 2.2
	6 " 7	**1 : 0.8 : 2.0**	**1 : 0.8 : 2.0**	**1 : 1.0 : 1.9**	**1 : 1.1 : 1.9**	**1 : 1.3 : 1.8**
	8 " 10	1 : 0.4 : 1.2	1 : 0.4 : 1.2	1 : 0.5 : 1.2	1 : 0.6 : 1.2	1 : 0.7 : 1.1
⅜ to 1½ in.	½ to 1	1 : 1.4 : 3.5	1 : 1.5 : 3.4	1 : 1.7 : 3.4	1 : 2.0 : 3.3	1 : 2.3 : 3.1
	3 " 4	1 : 1.1 : 3.0	1 : 1.2 : 2.9	1 : 1.4 : 2.9	1 : 1.6 : 2.8	1 : 1.9 : 2.6
	6 " 7	**1 : 0.6 : 2.2**	**1 : 0.8 : 2.2**	**1 : 1.0 : 2.2**	**1 : 1.1 : 2.1**	**1 : 1.3 : 2.0**
	8 " 10	1 : 0.4 : 1.4	1 : 0.4 : 1.4	1 : 0.5 : 1.4	1 : 0.6 : 1.3	1 : 0.7 : 1.3
⅜ to 2 in.	½ to 1	1 : 1.3 : 4.0	1 : 1.4 : 4.0	1 : 1.6 : 4.0	1 : 1.9 : 3.9	1 : 2.1 : 3.8
	3 " 4	1 : 1.0 : 3.4	1 : 1.2 : 3.4	1 : 1.3 : 3.3	1 : 1.5 : 3.3	1 : 1.7 : 3.2
	6 " 7	**1 : 0.7 : 2.6**	**1 : 0.8 : 2.5**	**1 : 0.9 : 2.6**	**1 : 1.0 : 2.6**	**1 : 1.1 : 2.5**
	8 " 10	1 : 0.4 : 1.6	1 : 0.4 : 1.6	1 : 0.5 : 1.6	1 : 0.5 : 1.6	1 : 0.6 : 1.6
¾ to 1½ in.	½ to 1	1 : 1.6 : 3.2	1 : 1.8 : 3.2	1 : 2.1 : 3.2	1 : 2.4 : 3.1	1 : 2.7 : 2.9
	3 " 4	1 : 1.3 : 2.7	1 : 1.5 : 2.7	1 : 1.7 : 2.7	1 : 2.0 : 2.6	1 : 2.3 : 2.5
	6 " 7	**1 : 0.9 : 2.0**	**1 : 1.0 : 2.1**	**1 : 1.2 : 2.0**	**1 : 1.4 : 2.0**	**1 : 1.5 : 1.8**
	8 " 10	1 : 0.5 : 1.2	1 : 0.5 : 1.3	1 : 0.6 : 1.3	1 : 0.7 : 1.3	1 : 0.8 : 1.2
¾ to 2 in.	½ to 1	1 : 1.6 : 3.7	1 : 1.8 : 3.7	1 : 2.0 : 3.7	1 : 2.4 : 3.6	1 : 2.6 : 3.5
	3 " 4	1 : 1.3 : 3.1	1 : 1.5 : 3.1	1 : 1.6 : 3.1	1 : 1.9 : 3.1	1 : 2.2 : 3.0
	6 " 7	**1 : 0.9 : 2.4**	**1 : 1.1 : 2.4**	**1 : 1.1 : 2.4**	**1 : 1.3 : 2.4**	**1 : 1.5 : 2.3**
	8 " 10	1 : 0.5 : 1.5	1 : 0.5 : 1.5	1 : 0.6 : 1.5	1 : 0.7 : 1.5	1 : 0.8 : 1.5
¾ to 3 in.	½ to 1	1 : 1.6 : 4.2	1 : 1.8 : 4.2	1 : 2.0 : 4.2	1 : 2.3 : 4.1	1 : 2.6 : 4.0
	3 " 4	1 : 1.3 : 3.5	1 : 1.5 : 3.6	1 : 1.6 : 3.6	1 : 1.9 : 3.6	1 : 2.1 : 3.5
	6 " 7	**1 : 0.9 : 2.6**	**1 : 1.0 : 2.6**	**1 : 1.1 : 2.6**	**1 : 1.3 : 2.6**	**1 : 1.4 : 2.6**
	8 " 10	1 : 0.5 : 1.6	1 : 0.5 : 1.6	1 : 0.6 : 1.7	1 : 0.7 : 1.7	1 : 0.8 : 1.7

APPENDIX I.

STANDARD NOTATION.

All symbols used in the Tentative Specifications for Concrete and Reinforced Concrete have been collected here for convenience of reference. The symbols are in general defined in the text near the point where formulas occur. In a few instances the same symbol is used in two distinct senses; however, there is little danger of confusion from this source.

a = spacing of web reinforcement bars measured perpendicular to their direction (see Section 135);

a = width of face of column or pedestal;

α = angle between inclined web bars and longitudinal bars;

A = total net area of column, footing, or pedestal, exclusive of fireproofing;

A' = loaded area of pedestal, pier or footing;

A_c = $A(1-p)$ = net area of concrete core of column;

A'_c = net area of concrete in columns (total column area minus steel area);

A_s = effective cross-sectional area of metal reinforcement in tension in beams or compression in columns; and the effective cross-sectional area of metal reinforcement which crosses any of the principal design sections of a flat slab and which meets the requirements of Section 156;

A_v = total area of web reinforcement in tension within a distance of a (a_1, a_2, a_3, etc.) or the total area of all bars bent up in any one plane;

b = width of rectangular beam or width of flange of T-beam;

b' = width of stem of T-beam;

b_1 = dimension of the dropped panel of a flat slab in the direction parallel to l_1;[1]

c = base diameter of the largest right circular cone which lies entirely within the column (including the capital) whose vertex angle is 90 deg. and whose base is $1\frac{1}{2}$ in. below the bottom of the slab or the bottom of the dropped panel (see Fig. 14);

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[1] In flat slab design, the column strip and the middle strip to be used when considering moments in the direction of the dimension l are located and dimensioned as shown in Fig. 15. The dimension l_1 does not always represent the short length of the panel. When moments in the direction of the shorter panel length are considered, the dimensions l and l_1 are to be interchanged and strips corresponding to those shown in Fig. 15 but extending in the direction of the shorter panel length are to be considered.

c = projection of footing from face of column;

C = total compressive stress in concrete;

C' = total compressive stress in reinforcement;

d = depth from compression surface of beam or slab to center of longitudinal tension reinforcement;

d' = depth from compression surface of beam or slab to center of compression reinforcement;

E_c = modulus of elasticity of concrete in compression;

E_s = modulus of elasticity of steel in tension $= 30{,}000{,}000$ lb. per sq. in.;

f_c = compressive unit stress in extreme fiber of concrete;

f'_c = ultimate compressive strength of concrete at age of 28 days, based on tests of 6 by 12-in. or 8 by 16-in. cylinders made and tested in accordance with the Standard Methods of Making and Storing Specimens of Concrete in the Field (Appendix 14) and the Tentative Methods of Making Compression Tests of Concrete (Appendix 13);

f_r = compressive unit stress in metal core;

f_s = tensile unit stress in longitudinal reinforcement;

f'_s = compressive unit stress in longitudinal reinforcement;

f_v = tensile unit stress in web reinforcement;

h = unsupported length of column;

I = moment of inertia of a section about the neutral axis for bending;

j = ratio of lever arm of resisting couple to depth d;

jd = $d-z$ = arm of resisting couple;

k = ratio of depth of neutral axis to depth d;

l = span length of beam or slab (generally distance from center to center of supports; for special cases, see Sections 108 and 148);

l = span length of flat slab, center to center of columns, in the rectangular direction in which moments are considered;[1]

l_1 = span length of flat slab, center to center of columns, perpendicular to the rectangular direction in which moments are considered;[1]

M = bending moment or moment of resistance in general;

M_0 = sum of positive and negative bending moments in either rectangular direction, at the principal design sections of a panel of a flat slab;

n = E_s/E_c = ratio of modulus of elasticity of steel to that of concrete;

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[1] See footnote, p. 275.

o = perimeter of bar;

Σo = sum of perimeters of bars in one set;

p = ratio of effective area of tension reinforcement to effective area of concrete in beams $= A_s/bd$; and the ratio of effective area of longitudinal reinforcement to the area of the concrete core in columns;

p' = ratio of effective area of compression reinforcement to effective area of concrete in beams;

P = total safe axial load on column whose h/R is less than 40;

P' = total safe axial load on long column;

r = ratio of cross-sectional area of negative reinforcement which crosses entirely over the column capital of a flat slab or over the dropped panel, to the total cross-sectional area of the negative reinforcement in the two column strips;

r_a = permissible working stress in concrete over the loaded area of a pedestal, pier or footing;

R = ratio of positive or negative moment in two column strips or one middle strip of a flat slab, to M_0;

R = least radius of gyration of a section;

s = spacing of web members, measured at the neutral axis and in the direction of the longitudinal axis of the beam;

t = thickness of flange of T-beam;

t_1 = thickness of flat slab without dropped panels or thickness of a dropped panel (see Fig. 14);

t_2 = thickness of flat slab with dropped panels at points away from the dropped panel (see Fig 14);

T = total tensile stress in longitudinal reinforcement;

u = bond stress per unit of area of surface of bar;

v = shearing unit stress;

V = total shear;

V' = external shear on any section after deducting that carried by the concrete;

w = uniformly distributed load per unit of length of beam or slab;

w = upward reaction per unit of area of base of footing;

w' = uniformly distributed dead and live load per unit of area of a floor or roof;

W = total dead and live load uniformly distributed over a single panel area;

z = depth from compression surface of beam or slab to resultant of compressive stresses.

APPENDIX 2.

See Appendix 1 for explanation of symbols used in figures.

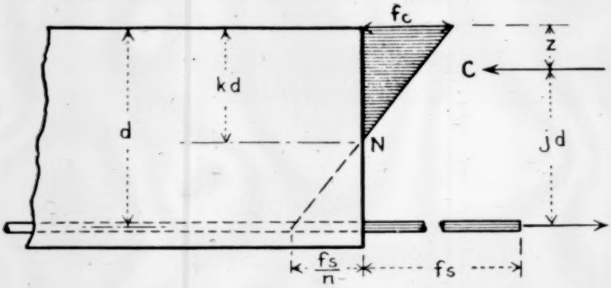

fc
z
C
kd
d
N
jd
T
fs/n
fs

FIG. 1.—Nomenclature for Concrete Beam Reinforced for Tension.

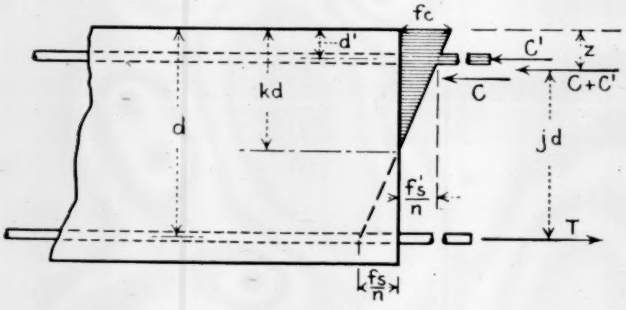

fc
d'
C'
z
C+C'
kd
C
d
jd
f's/n
T
fs/n

FIG. 2.—Nomenclature for Concrete Beam Reinforced for Tension and Compression.

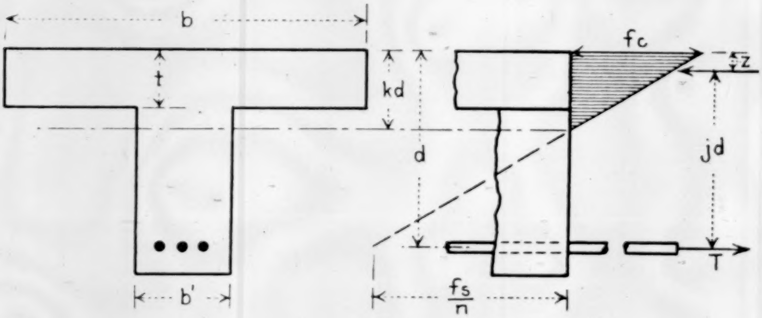

b
t
kd
d
fc
z
jd
T
b'
fs/n

FIG. 3.—Nomenclature for Reinforced Concrete T-Beam.

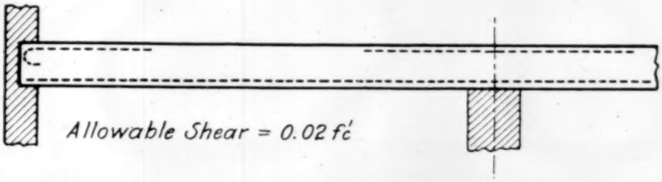

Allowable Shear = 0.02 f_c'

FIG. 4.—Typical Reinforced Concrete Beam; Principal Longitudinal Bars not Anchored.

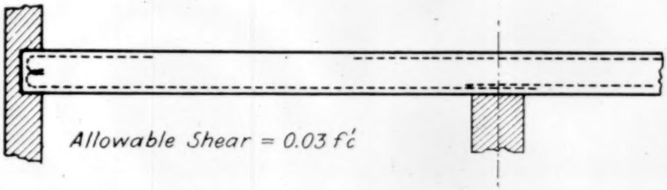

Allowable Shear = 0.03 f_c'

FIG. 5.—Typical Reinforced Concrete Beam; Principal Longitudinal Bars Anchored.

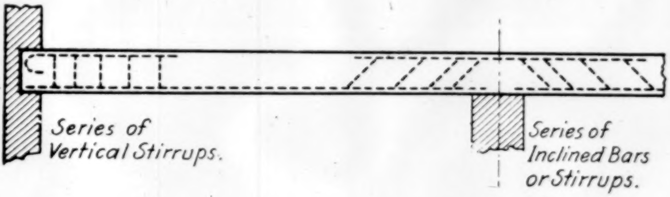

Series of
Vertical Stirrups.
Series of
Inclined Bars
or Stirrups.

FIG. 6.—Typical Reinforced Concrete Beam; Web Reinforced by Means of Series of Vertical Stirrups or Series of Inclined Bars or Stirrups.

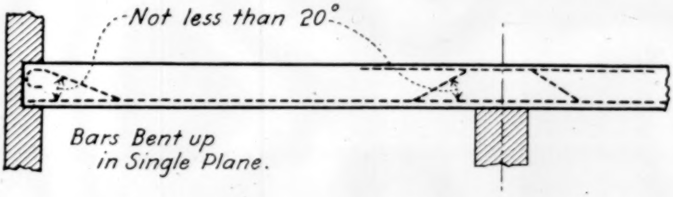

Not less than 20°
Bars Bent up
in Single Plane.

FIG. 7.—Typical Reinforced Concrete Beam; Principal Longitudinal Bars Bent up in Single Plane.

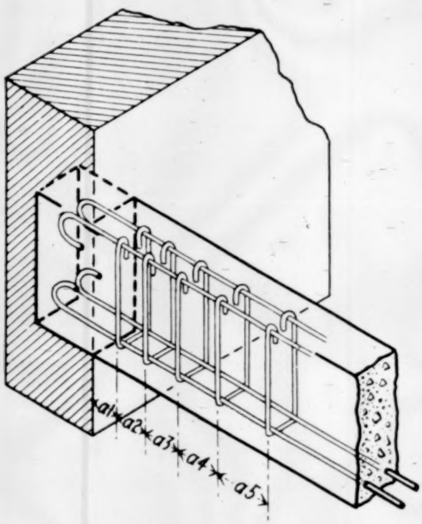

a1
a2
a3
a4
a5

FIG. 8.—Typical Reinforced Concrete Beam with Anchored Longitudinal Bars and Vertical Stirrups.

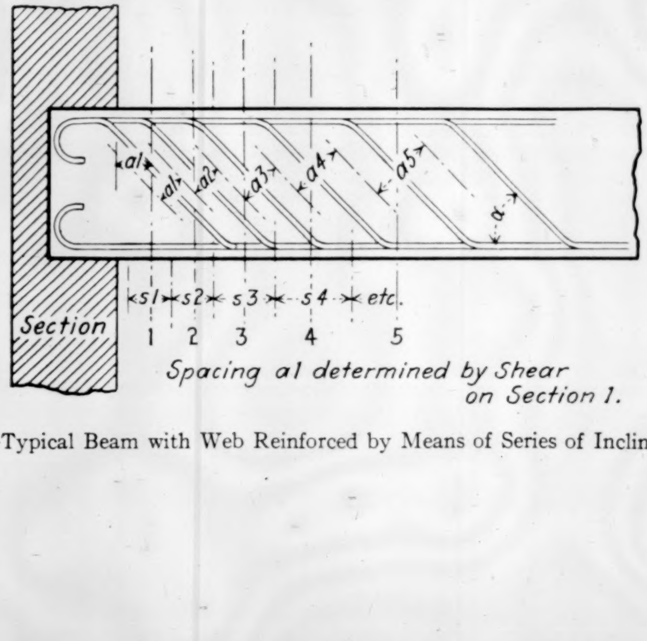

a1
a1
a2
a3
a4
a5
a
s1
s2
s3
s4
etc.
Section
1
2
3
4
5
Spacing a1 determined by Shear on Section 1.

FIG. 9.—Typical Beam with Web Reinforced by Means of Series of Inclined Bars.

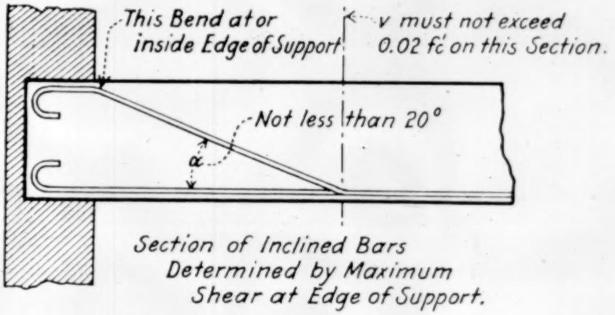

This Bend at or inside Edge of Support
v must not exceed 0.02 f'c on this Section.
Not less than 20°
α
Section of Inclined Bars Determined by Maximum Shear at Edge of Support.

FIG. 10.—Typical Beam with Web Reinforced by Means of Bars Bent up in Single Plane.

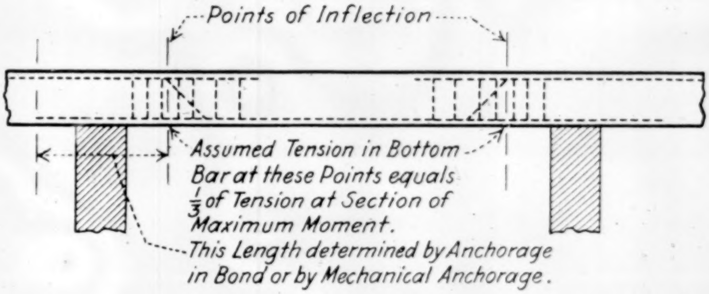

Points of Inflection
Assumed Tension in Bottom Bar at these Points equals $\frac{1}{3}$ of Tension at Section of Maximum Moment.
This Length determined by Anchorage in Bond or by Mechanical Anchorage.

FIG. 11.—Typical Web Reinforcement for Continuous Beams.

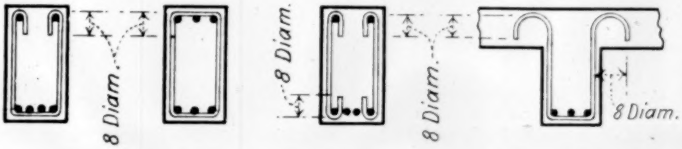

8 Diam.
8 Diam.
8 Diam.
8 Diam.

FIG. 12.—Typical Methods of Anchoring Vertical Stirrups.

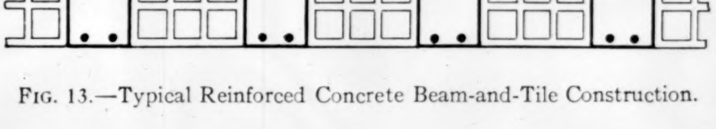


FIG. 13.—Typical Reinforced Concrete Beam-and-Tile Construction.

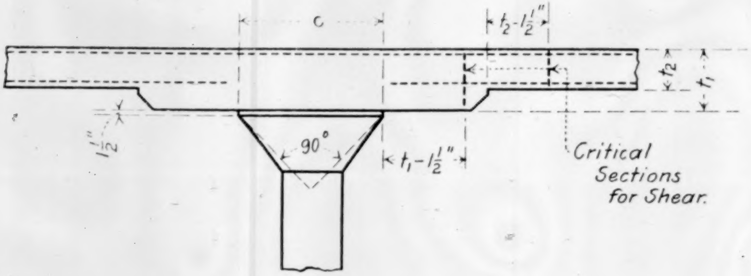

c
$t_2-1\frac{1}{2}''$
t_2
t_1
$1\frac{1}{2}''$
90°
$t_1-1\frac{1}{2}''$
Critical Sections for Shear.

FIG. 14.—Typical Column Capital and Sections of Flat Slab with Dropped Panel.

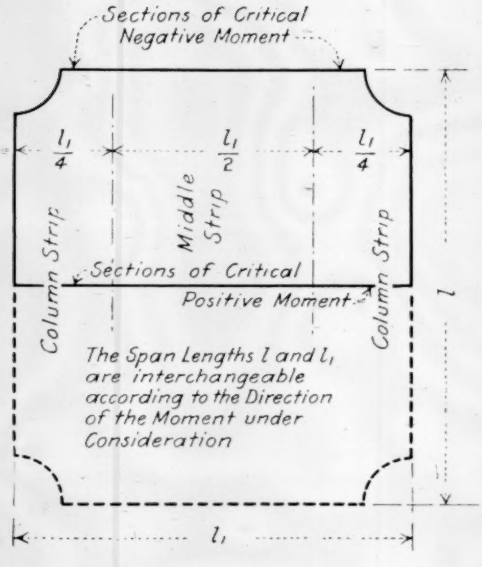
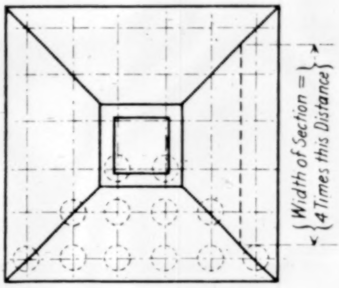
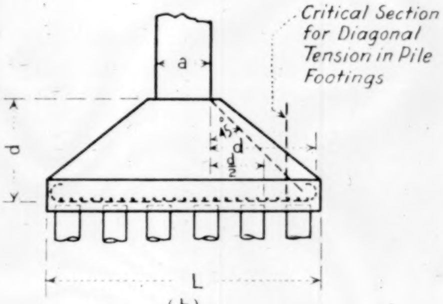

Sections of Critical Negative Moment
$\frac{l_1}{4}$
$\frac{l_1}{2}$
$\frac{l_1}{4}$
Column Strip
Middle Strip
Column Strip
Sections of Critical Positive Moment
l
The Span Lengths l and l_1 are interchangeable according to the Direction of the Moment under Consideration
l_1

FIG. 15.—Principal Design Sections of a Flat Slab.

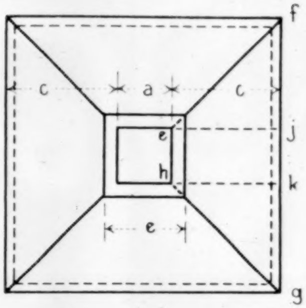

Width of Section = 4 Times this Distance

(a)
Plan.

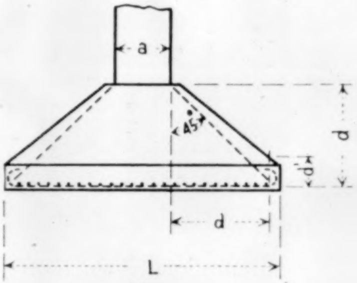

Critical Section for Diagonal Tension in Pile Footings
a
d
45°
d
$\frac{d}{2}$
L

(b)
Elevation.

FIG. 16.—Typical Sloped Reinforced Concrete Footing on Piles.


f
c
a
c
e
j
h
k
e
g

(a)
Plan.



(b)
Elevation.

FIG. 17.—Typical Sloped Reinforced Concrete Footing on Soil.

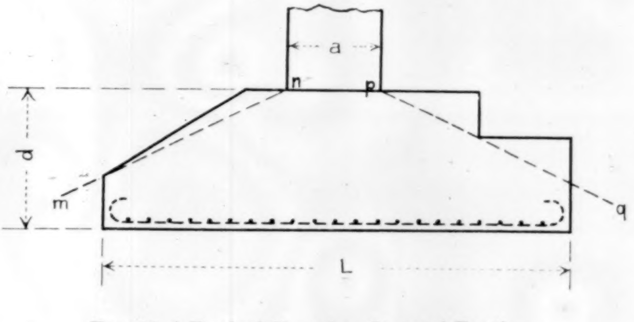


FIG. 18.—Typical Sloped or Stepped Footing.

REPORT OF COMMITTEE C-3
ON
BRICK.

Since the last annual meeting of the Society, Committee C-3 has held three meetings. The work of the committee has been somewhat handicapped by the resignation from the committee of both Chairman Orton and Secretary Bleininger. However, the necessary reorganization has been effected.

Several years ago in response to a request for specifications for clay sewer brick, a sub-committee was appointed for the purpose of drafting such specifications and in order to facilitate the work the membership of the committee was increased.

To determine more fully the needs of such a specification and to secure knowledge of what was generally accepted and in use by engineers throughout the country, correspondence was had with many engineers, and specifications for sewer brick were procured from nearly every city in the United States. All of these specifications differed in their requirements, which appeared to be based on the material available more than on service requirements. The first stage of studying these specifications now being completed, the committee is offering the appended specifications[1] to the Society for publication as tentative. The letter ballot vote of the committee on these specifications resulted as follows: Affirmative, 11; negative, 0; not voting, 0.

In compliance with a request from the Executive Committee, Committee C-3 has assumed jurisdiction over cement brick, and the membership will be enlarged to include manufacturers of this material.

This report has been submitted to letter ballot of the committee, which consists of 11 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. T. Shelley,
Chairman.

Warren E. Emley,
Secretary.

Editorial Note.

The proposed Tentative Specifications for Clay Sewer Brick were accepted for publication as tentative and appear on pages 527–532.

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[1] See p. 527.—Ed.

REPORT OF COMMITTEE C-4

ON

CLAY AND CEMENT SEWER PIPE.

Since the last annual report was issued, Committee C-4 has held two meetings both well attended.

No revisions have been voted on by the committee since the Tentative Specifications for Clay Sewer Pipe (C 13 - 18 T) as revised, and the Tentative Specifications for Cement-Concrete Sewer Pipe (C 14 - 18 T) as revised, were adopted by the Society as standard September 1, 1920.

The matters now principally engaging the attention of the sub-committees are briefly:

Sub-Committee I on Absorption and Hydrostatic Pressure Test Requirements.—Data on absorption of pipe materials by exposure to water otherwise than as prescribed in the boiling test.

Sub-Committee II on Chemical Requirements.—The presentation of data and the formulation of methods of research affecting the chemical requirements of sewer pipe materials.

Sub-Committee III on Dimensions and Their Permissible Variations.—This sub-committee has been reorganized so as to enlarge the facilities of the producer members in the study and formulation of desirable changes in the existing specifications for dimensions of sewer pipe and their permissible variations.

Sub-Committee IV on Methods of Testing will cooperate with Committee E-1.

Sub-Committee V on Nomenclature and Definitions.—This committee is engaged in formulating revised definitions for the terms Clay, Fire Clay and Shale,[1] as applicable to the materials suitable for manufacture of clay sewer pipe, and will cooperate with Committee E-8.

It is recommended that the Tentative Specifications for Required Safe Crushing Strengths of Sewer Pipe to Carry Loads from Ditch Filling (C 15 - 17 T)[2] be continued as tentative for another year.

This report has been submitted to letter ballot of the committee which consists of 25 members, of whom 20 have voted affirmatively none negatively, and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

RUDOLPH HERING,
Chairman,

GEORGE T. HAMMOND,
Secretary.

A. J. PROVOST, JR.,
Vice-Chairman.

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[1] For action taken at annual meeting in reference to definitions of terms Clay, Fire Clay, and Shale, see Summary of Proceedings, p. 22.—ED.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, pp. 603-4 (1920).

REPORT OF COMMITTEE C-6

ON

DRAIN TILE.

Committee C-6 has held two meetings during the year: one at Asbury Park, New Jersey, at the time of the annual meeting of the Society, and the other in Chicago, February 17, 1921.

The committee membership has been slightly changed during the year and now consists of sixteen members, equally divided between consumers and producers.

The committee hereby recommends for adoption as standard the revision of the Standard Specifications for Drain Tile (C 4 - 16),[1] published as tentative last year on page 817 of the 1920 Proceedings, Part I. The only important change included in the revision is the elimination from the freezing and thawing test of all boiling of specimens. Quoting from our 1920 report, "this important change is the result of active and extensive research work on freezing and thawing tests for surface-clay and for concrete drain tile," which were carried out during a period of four years at the Iowa Engineering Experiment Station and the Structural Materials Research Laboratory of the Lewis Institute, and which developed the interesting discovery that the boiling of specimens of concrete already set hard for a considerable time causes a marked decrease in tensile and compressive strength, at least for the time being, and consequently a decreased resistance (not due to inferior quality) to the results of freezing and thawing in tests made as specified in the Standard Specifications for Drain Tile (C 4 - 16). A similar effect of boiling, but not to the same extent, is observed in connection with surface-clay tile. The adoption as standard of the tentative revision as published during the past year is therefore urgently recommended.

An interesting development in the use of the Standard Specifications for Drain Tile has been in connection with the testing and inspection of drain tile for highway improvement. Highway engineers are just coming to realize the vital importance of thorough underdrainage in connection with all types of roads, and hundreds of thousands of miles of tile will be used in road drainage within the next few years. These tile are mostly 6 in. in diameter; very few exceed 12 in. The various highway departments have well-organized

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[1] 1918 Book of A.S.T.M. Standards.

Road Materials Departments, prepared to make tests of all road materials, and are starting now to apply the various tests and requirements of the A.S.T.M. Standard Specifications to small drain tile on a large scale.

This is the first time, so far as we can learn, that careful testing and inspection of small-sized drain tile by engineers has been carried out on a large scale. Undoubtedly this practice will prevail generally over the United States in the near future, in connection with the immense highway construction program now under way, probably one of the biggest engineering undertakings in the world.

We have to report that the main research investigation under general direction of Committee C-6 at the present time is the development of chemical tests and chemical test requirements for drain tile, to determine their resistance to the action of alkalies and acids in the soil. Experimental researches are under way, with the general coordination by Committee C-6 as follows:

1. The Iowa Engineering Experiment Station is conducting a series of laboratory tests on samples of concrete tile supplied by the U. S. Bureau of Standards and the Concrete Pipe Association from groups of tile which are being exposed to alkali soil conditions at various places in the United States. The object is to develop laboratory tests capable of indicating the resistance of tile to alkali soil conditions, and further to develop proper test requirements.

2. At the Structural Material Research Laboratory, Lewis Institute, Chicago, Ill., thousands of concrete cylinders are being made with different aggregates, cements, proportions and methods of mixing, in the effort to develop resistant concrete. Some of the cylinders will be exposed to actual severe alkali conditions in the field, and others will be subjected to laboratory tests.

3. The U. S. Bureau of Standards is continuing the work begun eight years ago on the investigation of resistance of concrete tile it alkali conditions. Unfortunately its activities in this work are seriously limited by lack of funds at the present time.

4. The Bureau of Public Roads and Rural Engineering of the U. S. Agricultural Department is conducting field and laboratory investigations on the resistance of concrete to alkali soil conditions.

5. The Concrete Pipe Association is conducting a series of field tests in which concrete pipe of different types are being exposed to alkali conditions in the field.

It is expected that the research investigations outlined above will need to continue at least two years to develop results which will warrant definite standard specifications on this important subject.

This report has been submitted to letter ballot of the committee, which consists of sixteen members, of whom 15 have voted affirmatively, none negatively, and one has refrained from voting.

Respectfully submitted on behalf of the committee,

ANSON MARSTON,
Chairman.

J. T. STEWART,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Drain Tile as presented in 1920 were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The specifications as thus revised appear in the 1921 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE C - 7
ON
LIME.

Committee C - 7 has held four meetings during the past year, as follows: June, 1920, Asbury Park, N. J.; October 4–5, 1920, Philadelphia, Pa.; January 11–12, 1921, Washington, D. C.; April 14–15, 1921, Washington, D. C. The attendance has been nearly double that of last year, reaching as high as 21 out of a membership of 34. Interest was well sustained, assigned duties were well performed, and substantial progress was made in several branches. Cooperation of outside agencies has been secured to a gratifying extent. A great deal of research work has been done by the members. The most notable accomplishments are as follows:

1. The preparation of specifications for "Finishing Hydrated Lime" to be included in the Tentative Specifications for Hydrated Lime for Structural Purposes.

It has been known to the trade for many years that certain hydrated limes, indistinguishable chemically from other limes, were far more plastic in use, but actual trial was the only test known. Through the chairman of Sub-committee VI, on Plasticity, Warren E. Emley of the U. S. Bureau of Standards, a mechanical method and apparatus for distinguishing positively between the two have been devised, tested, submitted to the committee, and accepted unanimously, after every opportunity had been given for criticism.

2. The Tentative Specifications for Masons' Hydrated Lime have been revised and simplified. The chief improvements are: that different allowances shall prevail when tested at the works or elsewhere, to allow for unavoidable deterioration en route, and that all analyses shall be reported on the non-volatile basis.

3. Similar changes have been made in the specifications for quicklime as revised by the committee.

4. Revision of the Tentative Methods of Chemical Analysis of Limestone, Lime and Hydrated Lime, submitted for approval of the Society.

Sub-Committee II on Structural Lime.—Specifications for quicklime and for hydrated lime for structural purposes are offered to the Society for publication as tentative as appended hereto,[1] the latter being a revision of the Tentative Specifications for Masons' Hydrated Lime (C 6 - 19 T).[2] It is accordingly requested that the present

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[1] See pp. 533–543.—Ed.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 605 (1920).

Standard Specifications for Quicklime (C 5 - 15)[1] and the Standard Specifications for Hydrated Lime (C 6 - 15)[1] be withdrawn.

The sub-committee now has under way an elaborate series of panel tests of lime plaster.

Research work is also being conducted to define the term "properly burned" by means of some measurable physical or chemical property.

A careful study of proposed tests for the quality of plaster has been made. It is believed that the quality of a plaster depends upon workmanship as well as upon materials. Since the Society has declined to take jurisdiction over questions involving workmanship, it is believed that this committee cannot function in the development of suitable tests for plaster, although it should be emphasized that the industry is badly in need of some such test.

The sub-committee has been conducting extensive research into the quality of sand suitable for use with lime as a plaster and as a mortar. It is expected that specifications for sand will be offered for consideration at the next meeting.

Sub-Committee III on Lime for the Chemical Industries.—This sub-committee has been studying specifications for lime in water softening, varnish making, glass manufacture, sulfite pulp, cooking of rags, and lime sulfur. Under the guidance of M. E. Holmes, its new chairman, it is believed that rapid progress will be made.

Cooperation with the inter-departmental conference on lime and with the American Chemical Society has been arranged, so that there will be no conflict of activity, and that each organization may have the benefit of the work, skill and experience available in the others.

The membership of this sub-committee is being enlarged, and it is the intention to invite representatives of each industry to join the Society and become members of the committee.

Sub-Committee IV on Agricultural Lime.—This sub-committee does not find it possible in the light of available information to bring forward any minimum specifications for lime for use on the soil. A wide variety of materials may be used, the controlling factor in their selection being the cost of effective oxides delivered on the land. Therefore, this entire problem must be approached from a different angle than might be used in other fields, such as lime for plaster, or for certain chemical uses. The policy is, therefore, to consider ways and means for dividing the different liming materials into reasonable and convenient grades, and to lay down definitions of those grades. The definition of such grades must depend in part upon the relative effects of the material in the soil, and this ties into the question of texture. For these reasons, the sub-committee's activity has been devoted to two points. The first is the extension of the study of the relation of fineness and texture of stone to the solubility of lime carbonate materials. Further progress has been made in this study by getting together samples of typical lime-carbonate formations in the country through consultation with the Geological Survey, and the agreement in detail in the committee upon the plan of the investigation to be undertaken. It will require a considerable period to carry out the investigations here outlined, and it can only be done through the cooperation of different laboratories. The second is the designation of grades of burnt forms of lime. This is in a very tentative condition, and will require further elaboration and submission to lime producers and users.

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[1] 1918 Book of A.S.T.M. Standards.

It will be evident from the above that the problem in the soil improvement field is to determine the methods and procedure for comparing different liming materials, and for conveying that information to the farmer. Such methods and procedure, of one type or another, are continually in active use by that large group of instructors of the farmer, the Agricultural Colleges and Experiment Stations, Departments of Agriculture and County Agents, and in laying down such methods due notice must be taken of their attitude on these questions. They are best expressed in the various state laws regulating the grading and inspection of agricultural liming materials. For this reason, much attention has been given to the standardization of the essential grades and methods which those laws employ. This has involved some reference to a standard agricultural lime inspection law in past records of this committee, but it has never been the thought that the American Society for Testing Materials could either adopt or support such a law as such, and the committee understands that the Society's interest is clearly concerned with setting up standards for materials and test methods. No standards that may be set up will be effective unless they rather fairly represent the consensus of opinion in the agricultural field.

Sub-Committee V on Methods of Analysis.—A revision of the Tentative Methods of Chemical Analysis of Limestone, Lime and Hydrated Lime has been worked out this year, and submitted to letter ballot of the committee. The methods have been revised by the introduction of sections for the determination of strontium, total sulfur, manganese and ferrous iron. The wording of other sections has been changed considerably. The methods are appended hereto[1] with the recommendation that they be accepted as tentative.

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[1] See p. 565.—ED.

The sub-committee is at the present time studying a method for the determination of "available lime." The determination of "available lime" will be especially valuable in those industries wherein water soluble calcium oxide is the chief factor in determining the value of lime for use in those industries.

The sub-committee adopted tentatively a method for the measurement of density of lump lime. This method, together with the method for the determination of "available lime," will be submitted to each sub-committee member, who will investigate the value of these methods in his own laboratory and report back to the sub-committee at a later date.

Sub-Committee VI on Plasticity.—During the past year this sub-committee has made a careful study of the methods of measuring plasticity. It has adopted for this purpose the plasticimeter designed by the Bureau of Standards. It has also recommended that a plasticity figure of 200, as determined by this instrument, shall be adopted as the line of demarcation between masons' hydrate and finishing hydrate. Both of these recommendations have been accepted and are included in the Tentative Specifications for Hydrated Lime for Structural Purposes.

The sub-committee is now endeavoring to adapt this instrument for the measurement of sand-carrying capacity, which will be used as a criterion for judging both lime and sand.

The sub-committee has been very active during the past year in attempting to determine the cause of plasticity. We are able to state that the plasticity of finishing hydrate is dependent upon its colloidal content. We are not yet prepared to state that there is any direct relation between plasticity and colloidal content, nor are we yet able to define the properties of the different kinds of colloidal matter which may occur in hydrated lime.

Sub-Committee VII on Highway Lime.—Much discussion has taken place during the past few years relative to the effect of hydrated lime on concrete mixtures. This material has been used to a certain extent in both concrete roadway and concrete masonry. In order that more information might be obtained regarding the effect of small additions of hydrated lime to the concrete mixtures used in road work, the cooperation of several state testing laboratories was secured and a program of investigation outlined. Some of the results of this investigation are now available and are presented as an appendix to this report.

Sub-Committee VIII on Nomenclature.—The sub-committee on nomenclature is comparatively new. It has devoted its attention to studying all existing definitions, and to drafting an index of definitions. It is too early to report any of the results.

Joint Committee on Slaking.—This joint committee has held three meetings and considerable correspondence during the year and has developed a set of directions for slaking lime, and for the preparation of mortar from putty. These directions have been transmitted to Sub-Committee II for inclusion with the specifications for quicklime, not as a part of the specification, but as information for the further protection of the purchaser.

This is a very decided step in advance, for many attempts have been made to write such directions but without success. This year's work has, however, received the unanimous approval of the committee, both producers and consumers.

The letter ballot vote of the committee on the recommendations contained in this report is as follows:

	AFFIRMATIVE.	NEGATIVE.	NOT VOTING.
Submission of the Proposed Tentative Specifications for Quicklime for Structural Purposes	31	0	3
Submission of the Proposed Tentative Specifications for Hydrated Lime for Structural Purposes	31	0	3
Revision of the Tentative Methods of Chemical Analysis of Limestone, Lime and Hydrated Lime (C 25 – 19 T)	24	0	10
Withdrawal of the present Standard Specifications for Quicklime (C 5 – 15)	31	0	3
Withdrawal of the present Standard Specifications for Hydrated Lime (C 6 – 15)	31	0	3

This report has been submitted to letter ballot of the committee which consists of 34 members of whom 31 have voted affirmatively, none negatively, and 3 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. C. BERRY,
Chairman.

L. H. HART,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Quicklime and of the Standard Specifications for Hydrated Lime referred to in this report were accepted for publication as new tentative standards and appear on pages 533–543. The standard specifications were accordingly withdrawn.

The proposed revisions of the Tentative Methods of Chemical Analysis of Limestone, Lime and Hydrated Lime were accepted. The methods as thus revised appear on pages 565–576.

APPENDIX.

COOPERATIVE TESTS ON EFFECT OF HYDRATED LIME ON CONCRETE MIXTURES.

In order that more information might be obtained regarding the effect of small additions of hydrated lime to the concrete mixtures used in roadwork, the cooperation of several state and university testing laboratories was secured and a program of investigation outlined under the auspices of Sub-Committee VII of Committee C-7.

The program consisted principally of compression and wear tests, but investigation of other qualities of hydrated lime, when used as noted, is being carried on.

The method of laboratory manipulation was left optional with each laboratory so that results of machine and hand-mixed concrete of different proportions, consistencies, curing, as well as allowing the use of various aggregates will be obtained. It was felt that by this procedure the effect of hydrated lime would be apparent under different circumstances. Test results from five laboratories are given below, the material being contributed by the following:

J. G. Bragg, Senior Testing Engineer, New Jersey State Highway Department.

H. S. Mattimore, Engineer of Tests, Pennsylvania State Highway Department.

H. F. Clemmer, Testing Engineer, Illinois Highway Division.

H. C. Berry, Professor of Civil Engineering, University of Pennsylvania.

G. W. Hutchinson, Testing Engineer, Delaware State Highway Department.

TESTS MADE BY NEW JERSEY STATE HIGHWAY DEPARTMENT.

The results reported by J. G. Bragg, New Jersey State Highway Department, consist of 48 compression tests on 6 by 12-in. cylinders. One set of aggregates, one consistency, two storage conditions and two mixtures (1 : 2 : 4 and 1 : 1½ : 3) were used.

The average of both storage conditions with the 1 : 1½ : 3 mixture shows a decrease in compressive strength of 8 per cent with 2½ per cent of hydrated lime added, but an increase of 5 per cent with the five per cent addition and an increase of one per cent with the 7½ per cent addition.

The average of both storage conditions with the 1 : 2 : 4 mixture shows an increase of 7 per cent with the 2½ per cent addition and a decrease of 5 and 10 per cent in the compressive strength with the 5 and 7½ per cent additions, respectively.

Machine-mixed concrete was used and the batches were of sufficient size to make one cylinder and one wear test block for each test gage.

A consistency which gave a slump of 2½ in. was maintained throughout the work.

AVERAGE OF 28-DAY COMPRESSION TESTS, LB. PER SQ. IN.

MIX.	HYDRATED LIME, PER CENT.	DAMP SAND STORAGE	AIR STORAGE.	AVERAGE.
1 : 1½ : 3	0	4427	3937	4182
	2½	3866	3848	3857
	5	4690	4085	4388
	7½	4515	3942	4229
1 : 2 : 4	0	3643	3270	3457
	2½	4058	3337	3698
	5	3388	3195	3292
	7½	3155	3048	3102

AVERAGE OF BOTH MIXES AND STORAGE CONDITIONS.

0 PER CENT LIME.	2½ PER CENT LIME.	5 PER CENT LIME.	7½ PER CENT LIME.
3819	3777	3840	3665

TESTS MADE BY PENNSYLVANIA STATE HIGHWAY DEPARTMENT.

The results reported by H. S. Mattimore, Pennsylvania State Highway Department, include tests of 36 6 by 12-in. cylinders. One mixture, one consistency, two test ages (7 and 28 day), one set of aggregates and two storage conditions were used.

The average of both storage conditions show a decrease of 5 per cent in compressive strength when 5 per cent of hydrated lime is added and a 12 per cent decrease when 10 per cent is added.

The specimens were made of 1 : 2 : 3 concrete in two-cylinder batch lots by hand, and a consistency maintained which gave a slump of 1½ in. The specimens were made by the standard laboratory method.

The analyses of the aggregates are as follows:

FINE AGGREGATE.

SIEVE.	PER CENT PASSING.
No. 100	2.7
No. 50	13.1
No. 40	25.1
No. 30	49.3
No. 20	65.2
No. 10	83.0
⅛-in	87.7
⅜-in	99.0

COARSE AGGREGATE.

SIEVE.	PER CENT PASSING.
½-in	2.5
¾-in	8.5
1 -in	20.7
1¼-in	38.5
1½-in	61.9
2 -in	100.0

AVERAGE OF 7 AND 28 DAY COMPRESSION TESTS, LB. PER. SQ. IN.

LIME, PER CENT.	DAMP SAND STORAGE.	AIR STORAGE.
7 DAY.		
0	2268	1466
5	1843	1347
10	1618	1151
28 DAY.		
0	3032	2519
5	2819	2464
10	2709	2162

AVERAGE OF 1 : 2 : 3 CONCRETE AND TWO STORAGE CONDITIONS AT 28 DAYS, LB. PER SQ. IN.

0 PER CENT LIME.	5 PER CENT LIME.	10 PER CENT LIME.
2776	2642	2436

TESTS MADE BY ILLINOIS HIGHWAY DIVISION.

The results reported by H. F. Clemmer, Illinois Highway Division, consist of thirty compression tests of 6 by 12-in. cylinders. One mixture (1 : 2 : 3½), two storage conditions, one set of aggregates and one consistency were used.

The average of all results show an increase of 6 per cent when 2½ per cent of hydrated lime was added, practically no effect with a five per cent addition and a loss of two per cent with a ten per cent addition.

The analyses of the aggregates are as follows:

FINE AGGREGATE.

SIEVE	PER CENT PASSING.
No. 100	2.0
No. 50	13.0
No. 40	31.0
No. 30	49.1
No. 20	71.0
No. 10	89.0
No. 8	95.0
¼-in	100.0

COARSE AGGREGATE.

SIEVE.	PER CENT PASSING.
¼-in	1.0
⅜-in	10.0
½-in	27.0
¾-in	71.0
1 -in	98.0
1¼-in	100.00

The consistency of the mixture was measured by means of the slump test. A consistency of from ½ to ¾ in. slump was maintained.

The quantity of materials per batch was determined by weight. Hydrated lime was added in varying quantities from 0 to 10 per cent by weight of the cement in the mix. The specimens were mixed in batches of four in a Blystone mixer. The concrete was placed in the molds in layers of 4 in. and each layer puddled by means of a pointed ½-in. round steel bar. The cylinders were removed from the molds and stored the following day.

The specimens for compression tests were tested in a Riehle testing machine of 200,000-lb. capacity. They were capped, previous to testing, with a thin layer of plaster of Paris and a spherical bearing block was used on top of the specimen.

One series of specimens was cured in damp sand for two weeks and then removed to cure in air until the 28-day period. The other series was cured in damp sand until tested.

AVERAGE OF 28-DAY COMPRESSION TESTS, LB. PER SQ. IN.

HYDRATED LIME, PER CENT.	ROADWAY STORAGE.	DAMP SAND.	AVERAGE.
0	3957	3128	3543
2½	4417	3085	3751
5	3793	3333	3563
7½	3606	3285	3446
10	3806	3122	3464

TESTS MADE AT LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA.

The results reported by H. C. Berry, of the University of Pennsylvania, are for forty-eight specimens consisting of 6 by 12-in. cylinders, and 8 by 8 by 5-in. blocks for the Talbot-Jones Rattler wear tests.

The series included zero per cent of lime and 5 per cent of lime with two mixtures, 1 : 2 : 4 and 1 : 2½ : 5. The specimens were tested at 28 days; each result is the average of three tests. Jersey gravel was used for fine aggregate and ¾-in. pebbles for coarse; specimens were stored in damp sand for 28 days. The concrete was mixed by hand in batches sufficient for 3 cylinders and 3 blocks. A slump test was made on each batch using the 4 by 8 by 12-in. truncated cone. The cement passed standard specifications.

The fine aggregate had a fineness modulus of 2.23. The comparative strength of 1 : 3 briquettes at 28 days was 94.5 per cent of those made with Ottawa Sand. The coarse aggregate had a fineness modulus of 7.2, a percentage of voids of 35.5.

In mixing, all quantities were weighed out on the basis of their respective specific weights. The batches to which 5 per cent of lime was added contained the same weights as those without lime. Six of the eight batches showed a slump of 1 in.; the first batch, when the pan was dry, had 2 in.

The wear specimens were tested at 28 days in a Talbot-Jones Rattler running 1800 revolutions in one hour, with a charge of 200 lb. of cast-iron shot, 125 lb. of which were small shot, $1\frac{1}{4}$ in. in diameter. For the first test the wear was reported in inches, but on account of the large loss it was difficult to determine accurately and was estimated by loss in weight. In the second test the loss by weight was carefully determined and from it the loss in thickness computed for the sake of comparison.

The results obtained from these tests are as follows:

	1 : 2 : 4 CONCRETE.		1 : 2½ : 5 CONCRETE.	
Percentage of Lime	0	5	0	5
Wear Tests:				
Loss by weight, per cent	24.9	26	16.6	27.2
Loss of thickness, per cent	21.0	25.6	16.6	26.4
Average variation of wear, per cent	2	3	1	2
Compressive strength, lb. per sq. in.	2257	2058	1979	1966
Variation, per cent	8	7	1	1½

TESTS MADE BY DELAWARE STATE HIGHWAY DEPARTMENT.

The results reported by the Delaware State Highway Department include compression tests of over four hundred 6 by 12-in. cylinders. Two mixtures, three storage conditions and nine sands were used.

The average of all mixes, sands, and storage conditions show an increase of approximately 1.5 per cent in the compressive strength when the 5 and 10-per-cent additions of hydrated lime were used. The 15-per-cent addition shows a decrease of 6 per cent.

It will be noted that the effect of the hydrated lime varied with the different kinds of fine aggregate. Some explanation of this may be derived from a comparison of the grading, as the percentage of increase in compressive strength is greater as the amount passing the No. 100 sieve grows less. Arundel and Honeybrook sands, with over 20 per cent passing the No. 100 sieve, show an immediate decrease with lime additions, while Sussex and Lewes, with one per cent passing the No. 100 sieve, show an increase when 5 per cent of hydrated lime is added.

Sufficient cement to cover the whole series was thoroughly mixed and stored in sealed galvanized iron barrels.

The fine aggregate was dried and stored in bins until used.

The coarse aggregate consisted of trap rock screened and divided into two sizes. One size passed a $1\frac{1}{2}$-in. screen and was retained on a $\frac{3}{4}$-in. screen, and the other size passed a $\frac{3}{4}$-in. screen and was retained on a $\frac{3}{8}$-in. screen. These sizes were combined in equal proportions to form the coarse aggregate for each batch.

All materials were tested prior to use and these tests were duplicated during the progress of the work.

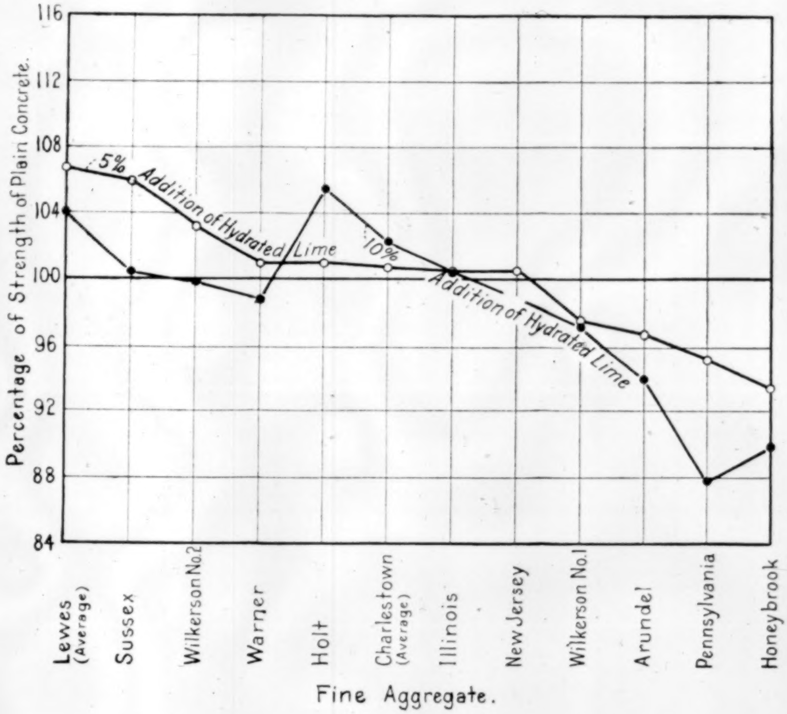

FIG. 1.—Variation in Compressive Strength with Various Fine Aggregate of Concrete Containing Hydrated Lime.

(Data from Table II, averaged from values for both 1 : 2 : 4 and 1 : 2½ : 5 concrete.)

All specimens were hand mixed in two-cylinder batch lots. The cement, sand, and hydrated lime were mixed dry in a small hand mixer, equipped with baffle plates, etc., which gave a very uniform mixture in $1\frac{1}{2}$ minutes. After being mixed, these materials were deposited on a mixing board 4 ft. square, lined with galvanized iron, and sloped toward the center to prevent water loss. The stone and water were then added and the mass mixed for 3 minutes.

TABLE I.—SIEVE ANALYSES OF FINE AGGREGATE.

Sand.	Sieve Analysis, Per Cent Passing Each Sieve.						
	100	48	28	14	8	4	$\frac{3}{8}$-in.
Lewes	0.8	8.8	86.0	99.4	99.8	100.0	.....
Sussex	1.3	17.6	69.0	89.3	95.7	98.4	100.0
Wilkerson No. 2	3.5	24.8	65.9	84.9	92.7	97.8	100.0
Charlestown	3.8	18.0	41.7	58.9	76.4	98.3	100.0
Warner	2.8	12.5	55.6	69.7	80.6	94.6	100.0
Holt	3.4	31.7	75.0	91.6	96.8	98.9	100.0
Arundel	21.9	51.2	78.3	86.2	91.1	97.0	100.0
Honeybrook	23.7	31.5	49.7	70.0	83.3	94.5	100.0

TABLE II.—COMPRESSIVE STRENGTH OF CONCRETE WITH VARIOUS PERCENTAGES OF HYDRATED LIME ADDED.

(Each value is the average of four tests unless otherwise noted.)

Sand.	Strength, lb. per sq. in.				Strength, per cent.			
	0 Per Cent of Lime.	5 Per Cent of Lime.	10 Per Cent of Lime.	15 Per Cent of Lime.	0 Per Cent of Lime.	5 Per Cent of Lime.	10 Per Cent of Lime.	15 Per Cent of Lime.
1 : 2 : 4 CONCRETE, ROADWAY STORAGE. (Two weeks in damp sand, then buried outdoors with tops exposed.)								
Lewes	2998[1]	3280[1]	3357[1]	....	100.0	109.4	112.0	.....
Sussex	3043	3218	3058	3013	100.0	105.8	100.4	99.0
Wilkerson No. 2	2943	3038	2937	2842	100.0	103.2	99.8	96.6
Charlestown	2347[1]	2410[1]	2536[1]	2374[1]	100.0	102.7	108.1	101.2
Warner	2714	2741	2678	2489	100.0	101.0	98.7	91.7
Holt	2860	2889	3014	2842	100.0	101.0	105.4	99.4
Wilkerson No. 1	3182	3101	3091	2955	100.0	97.5	97.1	92.9
Arundel	1931	1857	1813	1833	100.0	96.7	93.9	94.9
Honeybrook	2011	1879	1806	1708	100.0	93.4	89.8	84.9
Average	2670	2713	2699	2507	100.0	101.6	101.1	93.9
1 : 2 : 4 CONCRETE, DAMP SAND STORAGE.								
Lewes	3298[1]	3420[1]	3356[1]	....	100.0	103.7	101.8	.....
Charlestown	2686[1]	2493[1]	2664[1]	2777[1]	100.0	92.8	99.2	103.4
1 : 2 : 4 CONCRETE, LABORATORY AIR STORAGE.								
Lewes	2279[1]	2443[1]	2391[1]	.....	100.0	107.2	104.9	.....
Charlestown	1679[1]	1766[1]	1751[1]	1770[1]	100.0	105.2	104.3	105.4
1 : 2½ : 5 CONCRETE, ROADWAY STORAGE.								
Lewes	2013[1]	2122[1]	2080[1]	1952[1]	100.0	105.4	103.3	97.0
Charlestown	2118[1]	2135[1]	2053[1]	1958[1]	100.0	100.8	96.9	92.4
1 : 2½ : 5 CONCRETE, DAMP SAND STORAGE.								
Lewes	2337[1]	2564[1]	2433[1]	2193[1]	100.0	109.7	104.1	93.8
Charlestown	2097[1]	2240[1]	2260[1]	2160[1]	100.0	106.8	107.8	103.0
1 : 2½ : 5 CONCRETE, LABORATORY AIR STORAGE.								
Lewes	1593[1]	1645[1]	1493[1]	1415[1]	100.0	103.3	93.7	88.8
Charlestown	1369[1]	1318[1]	1308[1]	1210[1]	100.0	96.3	95.5	88.4

[1] Average of 6 tests.

Tests of consistency were made by taking the concrete from the mixing board and placing in the truncated cone upon the flow table, and then transferring to the truncated cone for the slump test. The flow table test was made by placing the concrete in a mold, and measuring the diameter of the mass after being given 15 drops of ½ in. each, at the rate of 45 drops per minute. The original diameter of the mass (12 in.) was taken as 100. A mixture having a diameter of 18 in., after being tested, would be recorded as having a flowability factor of 150.

TABLE III.—CONSISTENCY OF MIXTURES FOR VARIOUS PERCENTAGES OF LIME ADDED.

Sand.	0 Per Cent Lime Added.		5 Per Cent Lime Added.		10 Per Cent Lime Added.		15 Per Cent Lime Added.	
	Flow Table Value.	Water-Cement Ratio.	Flow Table Value.	Water-Cement Ratio.	Flow Table Value.	Water-Cement Ratio.	Flow Table Value.	Water-Cement Ratio.
1 : 2 : 4 CONCRETE.								
Lewes	147	0.850	139	0.876	139	0.902	...	.....
Sussex	169	0.890	169	0.925	167	0.960	171	0.995
Wilkerson No. 2	171	0.850	168	0.885	170	0.920	166	0.955
Charlestown	182	0.930	181	0.970	179	1.010	180	1.050
Warner	165	0.890	160	0.925	160	0.960	174	0.995
Holt	168	0.908	168	0.945	167	0.978	172	1.013
Wilkerson No. 1	158	0.850	163	0.885	164	0.920	164	0.959
Arundel	161	1.100	161	1.154	167	1.190	164	1.205
Honeybrook	165	1.125	165	1.183	164	1.245	166	1.300
1 : 2½ : 5 CONCRETE.								
Lewes	161	1.00	153	1.06	164	1.12	169	1.18
Charlestown	169	1.00	174	1.05	170	1.10	174	1.15

The cylinders were molded on a machined cast-iron plate and were capped on both ends with a mixture of neat cement paste. They were removed from the molds at the end of 24 hours and then marked and stored. Previous to testing, the ends were finished by grinding with powdered emery on a metal plate. The specimens were tested in an Olsen universal testing machine of 100,000-lb. capacity with the spherical bearing block on top.

All specimens were made in sets. One set consisted of two specimens made from one fine aggregate and included each percentage of hydrated lime. The results given are the average values of either two or three sets made on different days.

DISCUSSION.

Mr. Abrams.

MR. DUFF A. ABRAMS.—I wish to discuss the report of the Sub-Committee on Hydrated Lime for Highway Purposes, particularly the effect of hydrated lime on the strength of concrete. Last year I presented a paper to the Society under the title "Effect of Hydrated Lime and Other Powdered Admixtures in Concrete," giving the results of tests carried out at the Structural Materials Research Laboratory, Lewis Institute, Chicago.[1] That report summarized several thousand tests; mostly on strength, some on wear. The principal tests were made with hydrated lime as an admixture; some tests were made with other admixtures.

The following are the principal conclusions from the abovementioned report which refer to the effect of hydrated lime in concrete; they are given here in introducing the additional data which I shall present:

1. In general the addition of powdered materials reduced the strength of concrete approximately in proportion to the quantity of admixture. Some exceptions are noted below.

2. In usual concrete mixtures, each 1 per cent of hydrated lime (in terms of the volume of cement) reduced the compressive strength 0.5 per cent.

3. High calcium and high magnesium limes produced the same effect.

6. Rich concrete mixes showed a greater loss in strength due to powdered admixtures than the leaner ones.

7. The wetter mixes showed a greater loss in strength than the dry, due to the addition of hydrated lime.

10. Hydrated lime and other powdered admixtures used in these tests slightly increased the workability of the leaner mixes as measured by the slump test.

As a result of certain criticisms of the data in our earlier report another series of tests (Series 147) was carried out during the past year.

Compression tests were made at the age of 28 days on 1720 6 by 12-in. concrete cylinders with the following objects in view:

(1) To determine the nature of the relation between the quantity of hydrated lime and the strength of concrete for small percentages of lime.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part II, p. 149 (1920).

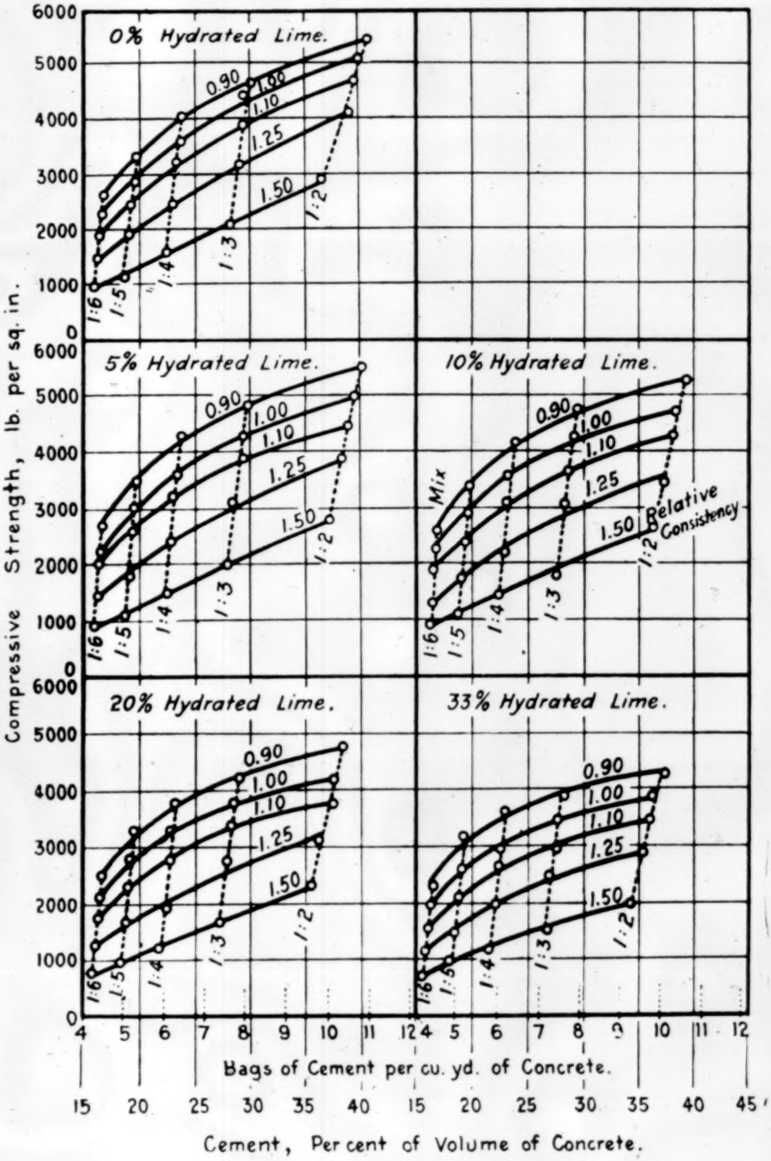

FIG. 1.—Effect of Quantity of Cement on the Strength of Concrete.

Compression tests of 6 by 12-in. cylinders at 28 days. Data from Group 1. (Table I.)

Mr. Abrams. (2) To study the effect of the addition of small quantities of Portland cement in same manner as hydrated lime.

(3) To secure additional data on the effect of hydrated lime up to 33 per cent of the volume of cement in the batch.

(4) To repeat certain tests in earlier series in which concrete of a wide range of mixtures and consistencies was used.

(5) To make further studies of the effect of hydrated lime on the workability or plasticity of concrete.

(6) To compare pebbles and crushed limestone as coarse aggregates in concrete in which hydrated lime was used.

(7) To secure average values of greater accuracy by making 10 tests instead of 5 as in earlier investigations.

In general, materials and test methods were similar to those used in earlier tests. The fine aggregate was a well-graded sand; in general, pebbles graded up to $1\frac{1}{2}$ in. were used as coarse aggregate. Crushed limestone was also used in one group of tests. Cylinders were molded in metal forms. The quantity of materials required for one specimen (about $\frac{1}{5}$ cu. ft.) was proportioned and mixed in a batch. Mixing was done by hand with a bricklayer's trowel in shallow galvanized iron pans. All mixtures are expressed as 1 volume of cement to a given number of volumes of mixed aggregate as used.

In general, the quantity of mixing water was predetermined. The quantity added to compensate for the presence of hydrated lime (or additional cement) was proportional to the quantity of hydrated lime (or cement) and to its normal consistency.

The plasticity or workability of each batch was measured by means of the "flow-table"[1] using a truncated cone mold, $6\frac{3}{4}$ in. in top diameter, 10 in. in bottom diameter and 5 in. high. The table was raised and dropped 15 times in about 8 seconds. The "flow" is the average base diameter of the concrete after the completion of the test, expressed as a percentage of the original diameter The same concrete was used in molding a compression cylinder.

One specimen of each kind was made before beginning a second round; this process was continued until 10 specimens of each kind were made. It will be seen that in this way each value in the tables is the average of 10 independent tests.

Concrete specimens were stored in a moist room until tested at the age of 28 days.

Group 1—Effect of Mix, Quantity of Hydrated Lime and Consistency of Concrete.—Concrete mixtures ranged from 1 : 6 to 1 : 2, and relative

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[1] One design of flow-table is described and illustrated in *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part II (1920), p. 242, and in "Concrete," June, 1920, p. 274.

TABLE I.—EFFECT OF HYDRATED LIME IN CONCRETE.

Group 1.—Different Mixes and Consistencies.

Compression tests of 6 by 12-in. cylinders. Age at test, 28 days.
Aggregate: sand and pebbles from Elgin, Ill., graded 0–1½ in.
Specimens stored in moist room until day of test.
Each value is the average of 10 tests made on different days.

Hydrated Lime, Per cent of Volume of Cement.	"Flow" of Concrete of Different Relative Consistencies.					Compressive Strength of Concrete of Different Relative Consistencies, lb. per sq. in.				
	0.90	1.00	1.10	1.25	1.50	0.90	1.00	1.10	1.25	1.50
MIX 1 : 6 BY VOLUME.										
0	146	170	195	217	222	2630	2270	1830	1490	980
5	149	180	203	220	230	2680	2180	1980	1430	900
10	147	182	204	226	231	2560	2190	1870	1300	890
20	152	187	212	232	232	2470	2080	1740	1240	790
33	149	194	223	235	236	2310	1930	1520	1160	650
Average	149	183	207	226	230	2530	2130	1790	1380	840
MIX 1 : 5 BY VOLUME.										
0	143	182	215	232[1]	254[2]	3350	2890	2450	1860[1]	1100
5	143	188	217	237	254[2]	3460	3020	2580	1700	1060
10	140	194	216	232	254[2]	3380	2890	2370	1660	1050
20	145	194	217	238	254[2]	3140	2780	2300	1620	960
33	142	196	225	241	254[2]	3180	2590	2110	1470	940
Average	143	191	218	236	254[2]	3300	2830	2360	1660	1020
MIX 1 : 4 BY VOLUME.										
0	148	192	225[1]	244[1]	254[2]	4080	3600	3270[1]	2440[1]	1590
5	151	191	222	243	254[2]	4290	3600	3200	2360	1460
10	147	191	224	242	254[2]	4180	3520	3090	2170	1400
20	154	204	231	254[2]	254[2]	3780	3260	2760	1880	1180
33	144	200	233	254[2]	254[2]	3590	2930	2610	1990	1130
Average	149	196	227	247[2]	254[2]	3980	3380	2990	2170	1350
MIX 1 : 3 BY VOLUME.										
0	144	194	234	254[2]	254[2]	4670	4440	3900	3180	2060
5	151	201	237	254[2]	254[2]	4800	4280	3870	3050	1980
10	145	196	234	254[2]	254[2]	4780	4230	3650	3010	1780
20	144	190	230	254[2]	254[2]	4180	3730	3390	2740	1610
33	147	202	239	254[2]	254[2]	3820	3420	2910	2470	1490
Average	146	197	235	254[2]	254[2]	4450	4020	3540	2890	1780
MIX 1 : 2 BY VOLUME.										
0	145	192	232	254[2]	254[2]	5480	5100	4720	4050	2910
5	150	197	234	254[2]	254[2]	5460	4980	4440	3840	2790
10	144	197	233	254[2]	254[2]	5260	4690	4290	3460	2610
20	148	194	233	254[2]	254[2]	4770	4140	3750	3090	2300
33	140	190	228	254[2]	254[2]	4240	3840	3350	2830	1910
Average	145	194	232	254[2]	254[2]	5040	4550	4110	3450	2500

[1] Average of 30 tests, 10 from each of 3 independent sets of tests in Groups 1, 3 and 4; 1860 average of 1790, 1880, 1900; 3270 average of 3250, 3240, 3330 and 2440 average of 2420, 2390, 2510. (Compare Table V.)

[2] **Exceeded diameter of table.**

Mr. Abrams. consistencies from 0.90 to 1.50 (consistencies from dry to "sloppy"). To each combination of mix and consistency hydrated lime was added in quantities of 0, 5, 10, 20, and 33 per cent of the volume of the cement. Cement weighed 94 and hydrated lime 40 lb. per cu. ft. The values for strength and "flow" are given in Table I and Figs. 1 and 2. This group repeated a part of the tests in Series 114 (1918) and Series 130 (1919–20).

Group 2—Comparison of Pebbles and Crushed Limestone as Coarse Aggregate.—Mix 1 : 4, relative consistency 1.10. Two different gradings of each coarse aggregate were used throughout with the same percentages of hydrated lime as in Group 1. Data in Table II and Fig. 3.

TABLE II.—EFFECT OF HYDRATED LIME IN CONCRETE.

Group 2.—Comparison of Pebbles and Crushed Limestone as Coarse Aggregate.

Compression tests of 6 by 12-in. cylinders.
Mix 1 : 4 by volume. Relative consistency, 1.10.
Age at test, 28 days.
Cement: a mixture of 5 brands of Portland cement purchased in Chicago.
Aggregate: Sand from Elgin, Ill., graded 0–No. 4 sieve. Pebbles from Elgin, Ill., graded No. 4–1½ in. Crushed Limestone from Chicago, graded No. 4–1½ in.
High-calcium hydrated lime was added to the materials in the batch; expressed as a percentage of the volume of cement.
Specimens stored in moist room until day of test.
Each value is the average of 10 tests made on different days.

Hydrated Lime, Per Cent of Volume of Cement.	"Flow" of Concrete.						Compressive Strength, lb. per sq. in.					
	Pebbles.			Crushed Limestone.			Pebbles.			Crushed Limestone.		
	5.50[1]	5.75[1]	Aver.	5.50[1]	5.75[1]	Aver.	5.50[1]	5.75[1]	Aver.	5.50[1]	5.75[1]	Aver.
0	228	225[2]	224	200	190	195	3200	3220[2]	3210	3240	3180	3210
5	231	222[2]	226	206	193	200	3200	3200[2]	3200	3070	3020	3040
10	228	224[2]	226	209	195	202	2960	3090[2]	3020	2980	2950	2960
20	239	231[2]	235	215	202	208	2810	2760[2]	2780	2840	2690	2760
33	233	233[2]	233	216	201	208	2510	2610[2]	2560	2540	2540	2540
Average	232	227[2]	229	209	196	203	2940	2980[2]	2950	2930	2880	2900

[1] Fineness modulus of aggregate, 5.75, was derived by mixing 30 per cent of sand and 70 per cent of pebbles or crushed limestone by volume; for 5.50, the values were 37 and 63 per cent.

[2] Same as values for 1 : 4 mix and relative consistency 1.10 in Table I (3220, average of 30 tests.)

Group 3—Comparison of Hydrated Lime and Portland Cement as Admixtures—Quantity of Mixing Water Constant.—Mixes 1 : 5 and 1 : 4. Tests were made with 1 and 2 per cent of "admixtures" in addition to the higher percentages used in Groups 1 and 2. The values are given in Table III and Fig. 4. This group differed from the others in that the *same quantity* of mixing water was used throughout for a given mix. The quantity of water for each specimen was fixed at an amount that would give a plastic concrete for the highest percentage of admixture, consequently the concrete became progressively drier and drier as hydrated lime or cement was added. The concrete without admixture was of relative consistency 1.25. These special conditions must be taken into account in interpreting the tests in this group and in comparing the values with those in Group 4.

Mr. Abrams.

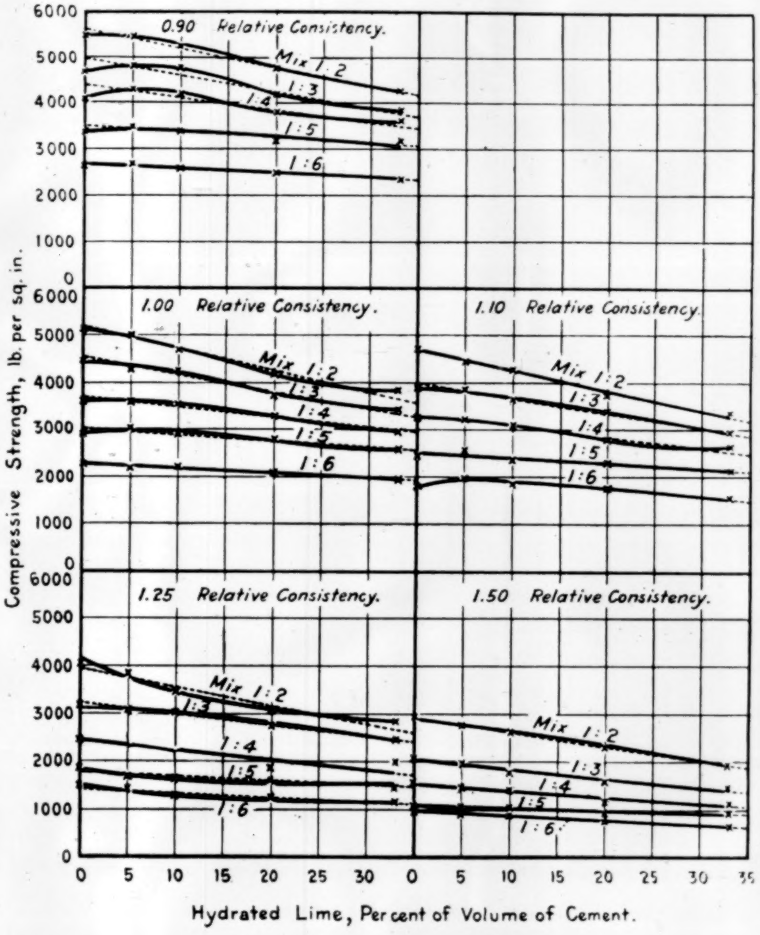

FIG. 2.—Effect of Hydrated Lime on the Strength of Concrete.
Compression tests of 6 by 12-in. cylinders at 28 days. Data from Group 1. (Table I.)

Group 4—Comparison of Hydrated Lime and Portland Cement as Admixtures—Mixing Water Proportioned to Give Uniform Flow.—Mix 1 : 4; differed from Group 3 in that the concrete was mixed as nearly as practicable to the *same workability or plasticity* as measured by the

Mr. Abrams. flow table. The attempt was made to secure the same flow for all percentages of admixtures; this required an increase in the quantity of mixing water as hydrated lime or cement was added. Data in Table III and Fig. 5.

The reduction in strength of concrete due to the presence of hydrated lime as shown by these tests is given in Table IV. Reduction in strength was calculated from the slopes of the curves in the figures and is expressed as percentages of the strength of concrete lost by the addition of 1 per cent of hydrated lime in terms of the volume of cement. If weight of lime is considered, multiply the values by 2.2.

TABLE III.—EFFECT OF HYDRATED LIME IN CONCRETE.

Comparison of Hydrated Lime and Portland Cement as "Admixtures."

Compression tests of 6 by 12-in. cylinders.
Age at test, 28 days.
Cement: a mixture of 5 brands of Portland cement purchased in Chicago.
Aggregate: sand and pebbles from Elgin, Ill., graded 0–1½ in.
High-calcium hydrated lime was added to the materials in the batch; expressed as a percentage of the volume of cement.
Specimens stored in moist room until day of test.
Each value is the average of 10 tests made on different days.

Admixture, Per Cent of Volume of Cement.	"Flow" of Concrete.						Compressive Strength, lb. per sq. in.					
	Mix 1 : 5		Mix 1 : 4		Average.		Mix 1 : 5		Mix 1 : 4		Average.	
	Hydrated Lime.	Cement.	Hydrated Lime.	Cement.	Hydrated Lime.	Cement.	Hydrated Lime.	Cement.	Hydrated Lime.	Cement.	Hydrated Lime.	Cement.
GROUP 3. MIXING WATER CONSTANT FOR EACH MIX, "FLOW" VARIABLE. CONCRETE WITHOUT ADMIXTURE OF RELATIVE CONSISTENCY 1.25.												
0	233	232	245	245	239	239	1900	1880	2510	2390	2210	2140
	(232)[1]		(244)[1]		(238)		(1890)[1]		(2440)[1]		(2160)	
1	235	230	239	242	237	236	1960	1950	2440	2520	2200	2240
2	231	227	238	240	234	234	1980	1990	2520	2610	2250	2300
5	232	230	237	240	234	235	1930	2060	2570	2770	2250	2410
10	229	237	231	232	230	234	2030	2410	2620	3100	2320	2750
20	231	229	229	233	230	231	2190	2790	2740	3500	2460	3140
33	220	223	212	216	216	220	2240	3410	2810	4080	2520	3740
GROUP 4. MIXING WATER INCREASED WITH ADMIXTURE TO PRODUCE CONSTANT "FLOW." CONCRETE WITHOUT ADMIXTURE OF RELATIVE CONSISTENCY 1.10.												
0	...	...	230	225	...	...	....	....	3180	3240	....	....
			(225)[1]						(3220)[1]			
1	...	...	229	226	...	...	....	....	3310	3280	....	....
2	...	...	229	229	...	...	....	....	3120	3130	....	....
5	...	...	231	222	...	...	....	....	3130	3540	....	....
10	...	...	231	218	...	...	....	....	3060	3510	....	....
20	...	...	226	224	...	...	....	....	2950	3830	....	....
33	...	...	222	218	...	...	....	....	2840	4290	....	....
		Aver.	228	223					3090	3540		

[1] Average of 30 tests, 10 each from the two independent sets of tests in the line above (without hydrated lime or additional cement), and 10 tests from the corresponding mixes in Group 1.

Mr. Abrams.

In 10 instances, duplicate sets of tests of concrete of the same kind were made independently at different points in the series and on different days (see Table V). The variation of duplicate averages, each based on 10 tests, ranged from 0 to 5.96 per cent with a grand average of 1.73 per cent. The maximum variation was somewhat high, but the average gave a value much lower than is generally considered possible in testing a material like concrete. These variations in average values indicate the weight which may be given a single average value in this series. It is believed that these tests represent about the limit of accuracy which it is possible to attain in testing concrete without making a very large number of specimens in each set. The same table gives a parallel study of the variation in flow readings. The variation in flow ranged from 0 to 10 per cent with a grand average of 3.8 per cent.

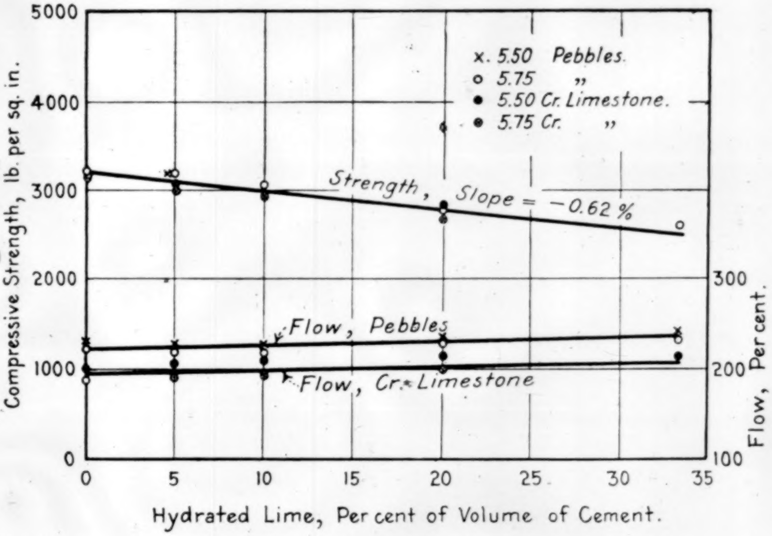

FIG. 3.—Effect of Hydrated Lime on the Strength of Concrete.

Compression tests of 6 by 12-in. cylinders at 28 days. Data from Group 2. (Table II.)

The indications of the tests in this series are quite definite, as would be expected when each average is based on 10 or more independent tests. It is interesting to note that these tests *confirm every conclusion based on our earlier investigations* in which repeat tests were made. The conclusions from this series may be stated briefly as follows:

Mr. Abrams. (*a*) Hydrated lime as an admixture reduced the compressive strength of concrete of all mixes and consistencies used in these tests.

(*b*) The reduction of concrete strength was nearly proportional to the quantity of hydrated lime used.

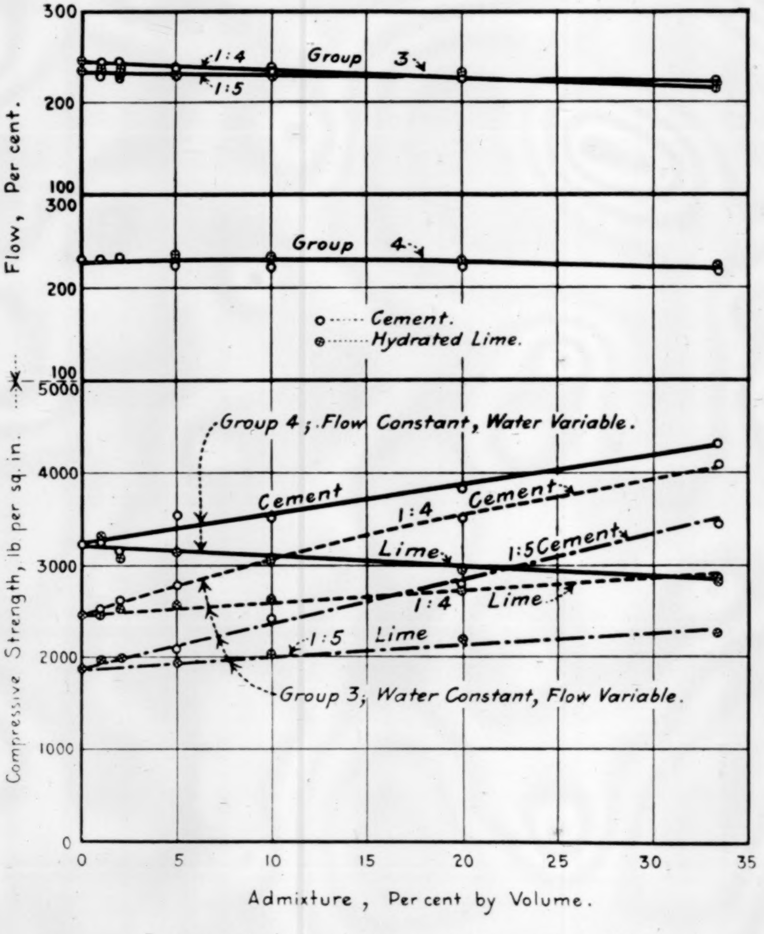

FIG. 4.—Effect of Hydrated Lime on the Strength of Concrete.
Compression tests of 6 by 12-in. cylinders at 28 days. Data from Group 3. (Table III.)

(*c*) Small percentages of hydrated lime (1, 2 and 5 per cent by volume of cement) shows the same rate of reduction in strength as larger percentages.

TABLE IV.—REDUCTION IN STRENGTH OF CONCRETE BY HYDRATED LIME.

Compression tests of 6 by 12-in. cylinders at age of 28 days.
Changes in strength are percentages for each 1 per cent addition of hydrated lime (by volume of cement).
The values were determined from the curves in Figs. 16 to 18.

Relative Consistency.	Kind of Aggregate.	Fineness Modulus of Aggregate.	Reduction in Strength.					
			1 : 6	1 : 5	1 : 4	1 : 3	1 : 2	Average.
GROUP 1. MIXING WATER INCREASED IN PROPORTION TO QUANTITY OF HYDRATED LIME AND ITS NORMAL CONSISTENCY.								
.90	Sand and pebbles	5.75	0.40	0.39	0.63	0.75	0.74	0.58
1.00	" " "	5.75	0.47	0.47	0.59	0.80	0.91	0.65
1.10	" " "	5.75	0.77	0.48	0.71	0.80	0.91	0.73
1.25	" " "	5.75	0.60	0.48	0.84	0.75	0.98	0.73
1.50	" " "	5.75	1.00	0.47	0.87	0.91	0.98	0.85
		Average.	0.65	0.46	0.72	0.80	0.90	0.71
GROUP 2. MIXING WATER INCREASED IN PROPORTION TO QUANTITY OF HYDRATED LIME AND ITS NORMAL CONSISTENCY.								
1.10	Sand and pebbles	5.50	....	....	0.62	....	....	0.62
"	" " "	5.75	....	....	0.62	....	....	0.62
"	Sand and crushed limestone	5.50	....	....	0.62	....	....	0.62
"	" " " "	5.75	....	....	0.62	....	....	0.62
		Average.	....	....	0.62	....	....	0.62
GROUP 3. MIXING WATER CONSTANT FOR ALL PERCENTAGES OF HYDRATED LIME; "FLOW" VARIABLE.								
1.25*a*	Sand and pebbles	5.75	....	+0.66*b*	+0.57*b*	....	....	+0.61
GROUP 4. MIXING WATER INCREASED WITH QUANTITY OF ADMIXTURE TO OBTAIN A CONSTANT "FLOW."								
1.10*c*	Sand and pebbles	5.75	....	....	0.34*d*	....	....	0.34

+ represents an increase in strength.

a Relative consistency of mix containing no hydrated lime was 1.25. As hydrated lime was added the mix became drier, or about 1.05 relative consistency for 33 per cent hydrated lime. It would be expected that hydrated lime would increase the strength of concrete under these conditions.

b The addition of Portland cement increased the strength of the concrete by 2.58 per cent and 2.25 per cent respectively. The "flow" was affected alike by hydrated lime and cement.

c Water calculated for concrete without hydrated lime. With the addition of hydrated lime sufficient water was added to keep "flow" approximately constant.

d Addition of cement in a like manner gave an increase of 1.00 per cent.

Mr. Abrams. (*d*) For usual concrete mixtures (1 : 4 and 1 : 5, relative consistencies 1.00, 1.10 and 1.25 in Group 1) the average reduction in strength was 0.59 per cent for each 1 per cent of hydrated lime added. Other tests in Groups 2 and 4 gave reductions of 0.62 and 0.34 per cent, respectively. Under the same condition the addition of 1 per cent of cement *increased* the strength of concrete about 1 per cent.

(*e*) Rich concrete mixtures showed a greater reduction in strength due to hydrated lime than lean ones.

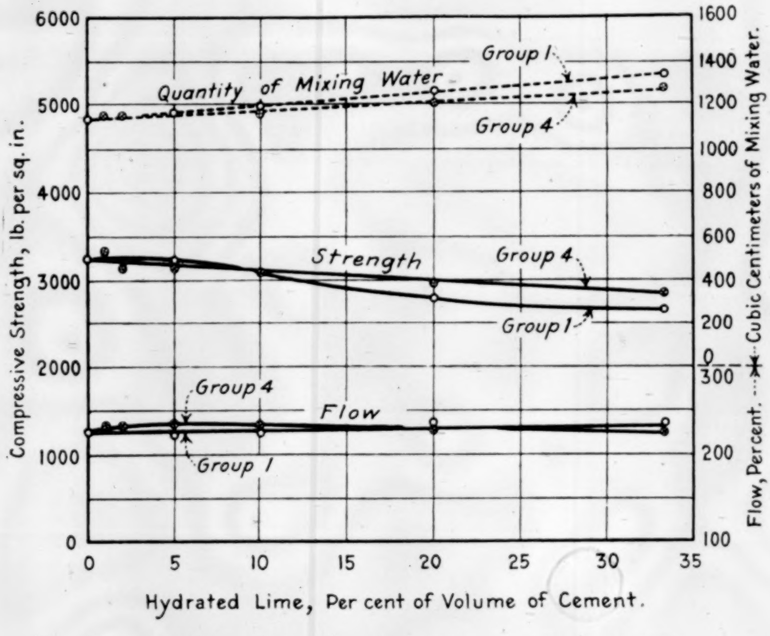

FIG. 5.—Effect of Hydrated Lime on the Strength of Concrete.

Compression tests of 6 by 12-in. cylinders at 28 days. Data from Groups 1 and 4. (Tables I and III.)

(*f*) The wetter mixes showed a greater loss in strength than dry, due to the addition of hydrated lime.

(*g*) Pebbles and crushed limestone as coarse aggregate gave almost identical concrete strengths and showed an equal reduction in strength by the addition of hydrated lime. The pebble-concrete showed a higher flow than the crushed-stone concrete.

(*h*) With a *constant quantity of mixing water* in 1 : 4 and 1 : 5 mixes (and of course a variable flow) hydrated lime showed an *increase* in strength of 0.61 per cent for each 1 per cent of lime, as compared

Mr. Abrams.

with an *increase* of 2.37 per cent for each 1 per cent of Portland cement added under the same conditions.

(*i*) In a single group of tests in which both hydrated lime and Portland cement were used as admixtures, and the quantity of mixing water was increased in order to produce concrete of the same plasticity (approximately equal flow) the lime showed a *reduction* in strength of the concrete of 0.34 per cent and the cement an *increase* in strength of 1.00 per cent for each 1 per cent by volume added to the original 1 : 4 mix.

(*j*) Concrete of usual mixtures and consistencies showed an increase in strength of about 1 per cent at 28 days for each 1 per cent of cement added.

TABLE V.—VARIATION IN PARALLEL SETS OF TESTS.

Aggregate: sand and pebbles, fineness modulus 5.75.
Concrete strength is given in pounds per square inch.

Groups.	Mix by Volume.	Relative Consistency.	Hydrated Lime, per cent.	Strength as Determined by Duplicate Sets of 10 Tests.				Flow as Determined by Duplicate Sets of 10 Tests.		
				First Set.	Second Set.	Difference.	Per Cent.	First Set.	Second Set.	Difference.[1]
1 and 3	1 : 5	1.25	0	1790	1880	90	4.90	230	232	2
1 and 3	1 : 5	1.25	0	1790	1900	110	5.96	230	230	0
3	1 : 5	1.25	0	1880	1900	20	1.06	232	230	2
1 and 4	1 : 4	1.10	0	3250	3240	10	0.31	221	225	4
1 and 4	1 : 4	1.10	0	3250	3330	80	2.43	221	230	9
4	1 : 4	1.10	0	3240	3330	90	2.74	225	230	5
1 and 3	1 : 4	1.25	0	2420	2390	30	1.24	242	245	3
1 and 3	1 : 4	1.25	0	2420	2510	90	3.65	242	245	3
3	1 : 4	1.25	0	2390	2510	120	4.90	245	245	0
3 and 4	1 : 4	1.10	33	2810	2840	30	1.06	212	222	10
						Average.	2.82	....	....	3.8

[1] Differences are also percentages based on the original base diameter of the truncated cone, "flow" = 100.

(*k*) The mean variation of the average values from duplicate sets of concrete tests each based on 10 specimens made on different days was 1.73 per cent with extreme variations of 0 and 5.96 per cent.

(*l*) The "flow-table" was a more satisfactory method of measuring plasticity or workablilty of concrete in the laboratory than the "slump test." The variations in the results of flow tests were much greater than the strength tests of the concrete. Variations of 5 to 10 points (percentage based on original diameter) may be expected in duplicate sets of 10 tests on identical concrete.

(*m*) In general, the "flow" of lean concrete mixtures was slightly increased and the "flow" of rich mixtures was little affected by the addition of hydrated lime. For usual mixtures and consistencies the

Mr. Abrams. correction for differences in "flow" produced an insignificant effect on the reduction in strength.

(*n*) Under identical circumstances the addition of either hydrated lime or Portland cement up to 33 per cent produced essentially the same effect on the "flow' of concrete.

(*o*) These tests show that for usual concrete mixtures a reduction in strength of about 10 per cent is produced by the addition of hydrated lime in percentages generally recommended by advocates of hydrated lime in concrete.

REPORT OF COMMITTEE C-8

ON

REFRACTORIES.

Committee C-8 has held three general meetings during the year.

The following recommendations submitted by the respective sub-committees have all been approved by the main committeee and were submitted to letter ballot vote. The results of this letter ballot in connection with each recommendation are given in tabular form at the end of the report.

Sub-Committee II on Analysis.—In pursuance of the report of Sub-committee II, the committee recommends that the present Tentative Method for Ultimate Chemical Analysis of Chrome Ores and Chrome Brick (C 18 – 20 T)[1] be submitted to letter ballot of the Society for adoption as standard.

Sub-Committee III on Industrial Survey.—This sub-committee has been investigating the conditions under which refractory materials are used in the blast furnaces and steel industry which work is practically completed. They are also investigating the coke-oven refractories and hope to be in a position shortly to issue a preliminary report.

Sub-Committee IV on Thermal Conductivity and Expansion.—This sub-committee has collected a large amount of information on methods and has in hand a considerable amount of work which has not yet progressed to the point where they can formulate definite recommendations.

Sub-Committee VII on Spalling Action.—In pursuance of the report of Sub-committee VII, the committee is presenting Method of Test for Resistance of Fire-Clay Brick to Spalling Action appended hereto,[2] and recommends that this method be published by the Society as a tentative standard.

Sub-Committee VIII on Slagging Action.—Considerable work has been done by members of the sub-committee on the Tentative Test for Slagging Action of Refractory Materials (C 17 – 19 T) but they are not ready, as yet, to ask that it be made standard. It was, therefore, voted to retain this as tentative for another year.

Sub-Committee IX on Nomenclature.—This sub-committee has proposed several definitions which have resulted in a great deal of helpful discussion before the general committee. They expect as a result of these discussions to be able to formulate several definitions during the coming year.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 647 (1920).

[2] See p. 577.—Ed.

Sub-Committee X on Micro Structure.—This sub-committee has been only recently formed and is at present engaged in collecting material.

The result of the letter ballot of the committees on the various recommendations is as follows:

	Affirmative.	Negative.	Not Voting.
I. RECOMMENDED FOR ADOPTION AS STANDARD.			
Tentative Method for Ultimate Chemical Analysis of Chrome Ores and Chrome Brick (C 18 - 20 T)	35	0	7
II. RECOMMENDED FOR PUBLICATION AS TENTATIVE.			
Proposed Method of Test for Resistance of Fire-Clay Brick to Spalling Action	39	1	2
III. RECOMMENDED TO BE CONTINUED AS TENTATIVE.			
Tentative Test for Slagging Action of Refractory Materials (C 17-19 T)	29	5	8

This report has been submitted to letter ballot of the committee, which consists of 42 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. C. PURDY,
Chairman.

W. H. FULWEILER,
Secretary.

EDITORIAL NOTE.

The Tentative Methods for Ultimate Chemical Analysis of Chrome Ores and Chrome Brick referred to in this report were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Books of A.S.T.M. Standards.

The proposed Tentative Method of Test for Resistance of Fire-Clay Brick to Spalling Action was accepted for publication as tentative and appears on pages 577–578.

REPORT OF COMMITTEE C-9
ON
CONCRETE AND CONCRETE AGGREGATES.

With this report are presented the following Tentative Standards:[1]

1. Proposed Tentative Methods for Making Compression Tests of Concrete.
2. Proposed Tentative Method of Test for Organic Impurities in Sands for Concrete.
3. Proposed Tentative Method of Test for Sieve Analysis of Aggregates for Concrete.
4. Proposed Tentative Method for Securing Specimens of Hardened Concrete from the Structure.
5. Proposed Tentative Specifications for Concrete Aggregates.

Tentative Standards along these lines have been previously presented and one of them, the Tentative Method of Determination of Voids in Fine Aggregate for Concrete (C 30 - 20 T), is continued as tentative without change at this time.

The committee recommends that the following tentative standards be advanced to standard:

Test for Unit Weight of Aggregate for Concrete (C 29 - 20 T);[2]

Method for Making and Storing Specimens of Concrete in the Field (C 31 - 20 T).[3]

In view of the importance of these specifications and their relations to the report of the Joint Committee on Reinforced Concrete which is now in preparation, a brief outline of the steps which have been followed in the researches upon which the Committee has been engaged is of interest together with a statement of certain important problems still under consideration.

To consider the work of Committee C-9, there must also be included the Committee on Aggregates of the American Concrete Institute, the formation of which preceded that of Committee C-9 by about three years, and since the appointment of Committee C-9 has met in joint session with it.

At the very beginning was recognized, as is indicated in the Institute Report of 1912, the importance of the aggregate in the make-up of the concrete and the necessity for well defined tests for acceptance and for economical use. Particularly, was evident the necessity for research in determining the laws for grading of aggregates, and also in determining the nature of organic matter deleterious to concrete and the formulation of tests for its presence in bank sands with means for overcoming its effect in concrete. These two features, grading and impurities, have become more and more the prime factors in dealing with materials for concrete.

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[1] See pp. 544-546 and 579-589.—Ed.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 624 (1920).

[3] *Ibid.*, p. 653.

From the series of tests first laid out by the Institute Committee and carried out by the various laboratories, college and commercial, definite conclusions were reached, some of which are enumerated below to again call attention to their importance. Almost the first step after the formation of Committee C-9 was the starting by the committee of a line of inquiry on organic matter in sands. For this purpose the committee raised funds through subscription and employed a chemist, Mr. Oscar E. Harder, who later came into the direct employ of the Lewis Institute of Chicago, and continued his researches with the advice of the committee. The funds thus provided, used for expenses such as the shipment of materials, etc., permitted development of several series of tests in college and commercial laboratories. These tests were chiefly of compression in concrete made up with different materials, different grading, and under different methods of manufacture and curing, together with supplementary series on mortars in tension, compression, and flexure. Also, an extensive series was carried through for a study of the methods of determining weights of aggregates. Later still, in 1920, a new series of tests for grading was laid out for laboratories for the purpose of studying the various theories of grading and reaching further conclusions.

Certain of the facts brought out through these various tests and researches, most of which are in regular accepted use at the present time, are outlined below. Conclusions and recommendations have been drawn, not from opinion, but from well thought-out series of comparative tests carried out in each case at several laboratories to eliminate the personal variations:

1. The cylindrical shape was found to be the best for concrete specimens.

2. A specimen having a height twice the diameter was selected. Shorter specimens, particularly below a ratio of $1\frac{1}{2}$ to 1, showed great change in strength with slight change in relative height. Beyond the 2 to 1 ratio, that is for longer specimens like columns, the difference in strength was but slight. The higher loads carried by the shorter specimens are ordinarily attributed to the effect of the restraint against lateral swelling of the test pieces under load, which is developed by the friction between the bearing plates of the testing machine and the ends of the test pieces.

3. The size of cylinder, 6 by 12 in., was in 1914 recommended for a maximum size stone of not greater than 1½ in., that is, one-fourth the diameter of the specimen. For larger stone, cylinders 8 by 16 in. were recommended, in general requiring the diameter of the cylinder to be at least four times the size of the largest stone particles; and for concrete aggregates of small size 4 by 8-in. cylinders were permissible. The advantages of the 6 by 12-in. cylinders over the 8 by 16-in. for ordinary uses are the lighter weight in handling on a job and the smaller quantities of material required in laboratory tests. Tests made under the auspices of the committee showed that within the limitations indicated the size of the specimen has practically no effect upon the strength provided the ratio of height to diameter is the same.

4. If tests are made on specimens having other ratios of height to diameter than 2 to 1, correction must be made for this difference in shape of specimen. With cubes or cylinders having a height equal to the diameter, it was found that the strength of the standard cylinder would be approximated by multiplying the cube strength by 0.73. Specimens with a height one-half the diameter, were 50 per cent stronger than the cube. To convert the strength to standard cylinder the strength of the half-cube must be multiplied by 0.48.[1]

5. Specimens of concrete stored in dry air from the time of mixing were found by tests of A. N. Talbot and H. F. Gonnerman to gain but slightly in strength from 28 days up to a period of several months or even years.

6. The decrease in strength through the addition of excess water is shown conclusively in the laboratory tests referred to.

7. The methods of manufacture of field specimens of concrete have been put into the form of a tentative standard.

8. The Chapman Consistency Test, now called the "Slump Test," was recommended in substantially its present form in 1914.

9. The Abrams-Harder test for Organic Impurities is one of the most important outgrowths of the committee researches. First presented by the committee in its report in 1919 and widely published through the bulletin of the Lewis Institute and the Portland Cement Association, it is this year included by the committee as a tentative standard[2].

10. Methods of tests for weights and voids have been put into the form of tentative standards as the result of a comprehensive series of tests by some six or eight laboratories.

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[1] The ratios for other strengths may be obtained from the curve in the Report of the Committee, *Proceedings*, American Concrete Institute, Vol. X, p. 424 (1914).

See p. 585.—ED.

11. The Tentative Specifications for Concrete Aggregates submitted herewith[1] have been compiled as a result of researches of the committee in cooperation with the sub-committee of the Joint Committee but as submitted they differ in some details from the present Tentative Joint Committe report.

The committee is not yet prepared to present well-defined recommendations for the most economical grading of aggregates. Comprehensive researches, based on the various laboratory tests, particularly those at Lewis Institute by D. A. Abrams and other series made by other members of the committee, notably A. N. Talbot, M. O. Withey, L. N. Edwards, R. B. Young, and the Bureau of Standards, furnish a source which is being used as a basis for deriving laws of concrete mixtures. As stated above, a series of tests is now in progress by various laboratories which should throw further light upon this most important problem.

Tentative specifications presented provide a basis for the acceptance of sand which will insure good concrete. The question of economical proportioning, however, which is of such great importance to the builder, cannot be satisfactorily treated by the committee on a basis of fact until further progress is made. However, individual members of the committee have worked out methods that have been adopted under many conditions in practice with large resulting economies in the use of cement. The methods of fineness modulus, water ratio, and surface areas have thus been used satisfactorily. It remains for the committee to go a little further into the science to clearly demonstrate the best practical rules to follow.

Lines of research in which the committee is engaged are:

1. Laws of mechanical mixtures of cement and aggregate as outlined above.

2. Further researches on impurities in natural aggregates.

3. Investigations of coarse aggregates to determine their relative importance and value for concrete mixtures. Included in this study is the use of slag for concrete, with the view to the formulation of rules for its acceptance.

4. The best type of specimen for mortar test, whether tensile briquettes, or compression cylinders, or transverse bars. Results so far show comparatively little choice between tension and compression, with the transverse test in less favor.

5. The distribution of aggregate materials throughout the country is being studied in collaboration with researches made by the Bureau of Standards.

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[1] See p. 544.—ED.

6. Specifications for concrete are being analyzed and reviewed, but largely in collaboration with the Joint Committee.

7. Testing of field concrete after it is in place is under investigation.

The results of a letter ballot of the committee upon the recommendations which have been made, relative to the adoption of tentative standards as standards and the submission of additional tentative standards is given in the accompanying table:

Items.	Affirmative.	Negative.	Not Voting.
I. PROPOSED NEW TENTATIVE STANDARDS.			
Proposed Tentative Methods of Making Compression Tests of Concrete	21	4	9
Proposed Tentative Method of Test for Organic Impurities in Sands for Concrete	23	1	10
Proposed Tentative Method of Test for Sieve Analysis of Aggregates for Concrete	22	0	12
Proposed Tentative Method of Securing Specimens of Hardened Concrete from the Structure	24	0	10
Proposed Tentative Specifications for Concrete Aggregates	19	6	9
II. TENTATIVE STANDARDS RECOMMENDED FOR ADOPTION AS STANDARDS.			
Tentative Test for Unit Weight of Aggregate for Cement Concrete (C 29 - 20 T)	22	2	10
Tentative Methods for Making and Storing Specimens of Concrete in the Field (C 31 - 20 T)	24	0	10

This report has been submitted to letter ballot of the committee, which consists of 34 members, of whom 23 have voted affirmatively, none negatively, and 11 have refrained from voting.

Respectfully submitted on behalf of the committee,

SANFORD E. THOMPSON,
Chairman.

A. T. GOLDBECK,
Secretary.

EDITORIAL NOTE.

The Tentative Methods for Making and Storing Specimens of Concrete in the Field and the Tentative Test for Unit Weight of Concrete Aggregates for Cement Concrete referred to in this report were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards.

The proposed Tentative Methods of Making Compression Test of Concrete, the proposed Tentative Method of Test for Organic Impurities in Sands for Concrete, the proposed Tentative Method of Test for Sieve Analysis of Aggregates for Concrete and the proposed Tentative Method of Securing Specimens of Hardened Concrete from the Structure and the proposed Tentative Specifications for Concrete Aggregates were accepted for publication as tentative and appear on pages 544–546 and 579–589.

DISCUSSION.

Mr. Marcher. MR. R. J. MARCHER.—Referring to the Test for Organic Impurities in Sands, I should like to ask whether there is more than one kind of organic matter in the sand. Are there not acetic, organic and alkaline organic matter? If so, the color test is a warning only, and weakness in the sand cube breaks may be looked for in comparison with cubes made of the same sand washed. Otherwise, a chemical test of effluent water should be made.

Mr. Goldbeck. MR. A. T. GOLDBECK (*Secretary of Committee C-9*).—I think undoubtedly there are a number of kinds of organic matter in sand, but this test of course does not attempt to distinguish between kinds of organic matter. All it does attempt to do is to determine whether there is a serious amount of organic matter, the kind that is harmful to the strength of mortar.

Mr. Marcher. MR. MARCHER.—Does failure to pass the color test necessarily condemn the sand?

Mr. Goldbeck. MR. GOLDBECK.—That is open to interpretation. In our own practice in the Bureau of Public Roads, if the sand shows a dark color, but has a sufficiently high strength, we do not condemn the sand; in other words, we use the color test as a warning. There are cases where the grading of the sand when combined with the dark color test will give a low strength value. You may have a very fine grading combined with dark color resulting in low strength, while on the other hand you may have a very well graded sand combined with dark color in the test and obtain a very high strength value. In such cases as the latter, it is our practice to accept the sand.

Mr. Marcher. MR. MARCHER.—One thing beating the other?

Mr. Goldbeck. MR. GOLDBECK.—Yes.

Mr. Marcher. MR. MARCHER.—Just what is there in the organic matter that is destructive to cement or the setting of cement around sand?

Mr. Goldbeck. MR. GOLDBECK.—Tannic acid is regarded as one of the very serious things. Mr. Abrams and Mr. Harder are largely responsible for this test; perhaps they can answer your question.

Mr. Harder. MR. OSCAR E. HARDER.—Some of the things which have been investigated in that connection include tannic acid, sugar, gelatine and manure extract. Those materials, if applied to sand as a coating, will give a typical defective sand, and that applies particularly to such substances as manure extract. It is probably the general opinion

Mr. Harder.

that this material is largely of a humous nature, formed from the decomposition and humification of organic material which washed down with the solutions and finally deposited on the sand grains, and that it is such material in particular which produces the color in the colorimetric test. I do not think the coloration should be attributed to any one particular organic substance, but to a general class of substances which will produce that color.

REPORT OF COMMITTEE C-10
ON
HOLLOW BUILDING TILE.

Committee C-10 has held three meetings during the year and has prepared Tentative Definitions of Terms Relating to Hollow Tile; also Tentative Specifications for Clay Hollow Building Tile, appended hereto.[1]

In the Tentative Specifications for Clay Hollow Building Tile will be found two somewhat radical departures from precedent: namely, the absence of an absorption specification and the stipulation that test specimens for freezing test shall be sawed from unbroken tile. In regard to an absorption specification for hollow building tile, it may be said that this was omitted because the committee found it impossible to establish either a minimum or a maximum absorption requirement which would differentiate satisfactorily and consistently between acceptable tiles and those which should not be used. While it is known, in a general way, that extreme density means poor fire resistance, it is not possible at this time to establish a minimum absorption requirement based on fire test data. As to a figure for the maximum absorption, it has been found that while, with some raw materials, there is a fairly definite relation between absorption and strength, this relation does not apply to all raw materials. The absorption test is not, therefore, a satisfactory substitute for the strength test. If it should be possible at a later date to substitute, in most cases, the absorption test for the freezing test, this would be a step in advance. At present, however, but little is known of the relations between the absorption of hollow tile and their resistance to freezing. It would not be possible to make an absorption specification and to say, with any assurance whatever, that all tiles with a lower absorption than this would resist freezing satisfactorily and that all others would not. It seems best, therefore, to propose tentative specifications requiring the direct determination of strength and resistance to freezing and to leave out the absorption specification, at least until more conclusive information can be obtained.

The committee wishes to report that a somewhat elaborate investigation is being conducted for the purpose of studying the physical properties of hollow building tile with special reference to their fire resistance. The Hollow Building Tile Association is cooperating with the Bureau of Standards in carrying out this investigation. Data already obtained in this investigation have been of important assistance to the committee in the preparation of the tentative specifications, and it is expected that the information yet to be gained will be of great value.

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[1] See pp. 547 and 602.—Ed.

Reference has been made to the requirement that specimens for the freezing test shall be sawed from the unbroken tile. It has been found, in freezing tests of architectural terra cotta, that unbroken test specimens may resist freezing satisfactorily, although fragments from similar pieces do not. It seems reasonable to expect that this might be the case with clay products generally, since the soundness and strength of the fragments are likely to be affected by the breaking, either in a testing machine or otherwise. It is therefore considered necessary to obtain specimens for freezing by cutting instead of by breaking. The expense of the cutting is small.

The results of the letter ballot on this report are as follows:

	AFFIRMATIVE.	NEGATIVE.	NOT VOTING.
Acceptance of the definitions for publication as tentative	14	0	2
Acceptance of the specifications for publication as tentative	13	0	3
General Report	14	0	2

Respectfully submitted on behalf of the committee,

WALTER A. HULL,
Chairman.

CHARLES C. CROCKATT,
Secretary.

EDITORIAL NOTE.

The proposed Tentative Specifications for Clay Hollow Building Tile and the proposed Tentative Definitions of Terms Relating to Hollow Tile were accepted for publication as tentative and appear on pages 547–552 and 602–603, respectively.

REPORT OF COMMITTEE C-11

ON

GYPSUM.

Since the last annual meeting of the Society, Committee C-11 has held two meetings. It is felt that real progress has been made, owing to the interest and enthusiasm of the members.

Tentative Specifications for Gypsum.—The committee recommends that the Tentative Specifications for Gypsum (C 22 - 20 T)[1] be revised as follows:

In Section 3 (*b*) in place of the present permissible size for Crushed Gypsum substitute the following two sizes:

> "*No. 1.*—Material of this size shall all pass through a 3-in. (7.6-cm.) ring; not more than 30 per cent shall pass through a 100-mesh screen, and not less than 40 per cent shall be retained on a $\frac{3}{16}$-in. (0.469-cm.) or equal mesh screen.
>
> "*No. 2.*—Material of this size shall all pass through a 2-in. (5.08-cm.) ring; not more than 30 per cent shall pass through a 100-mesh screen, and not less than 10 per cent shall be retained on a $\frac{3}{16}$-in. (0.496-cm.) or equal mesh screen."

Also change the words "may be sold" to read "may be marketed."

The specifications as thus revised have been re-arranged and submitted to letter ballot of the committee for continuance as tentative with the following results: Affirmative, 23; negative, 0; not voting, 7.

Tentative Specifications for Calcined Gypsum.—The committee recommends that the Tentative Specifications for Calcined Gypsum (C 23 - 20 T)[2] be revised by omitting Sections 3 and 7 which deal with the classification of Calcined Gypsum according to chemical composition. It is also recommended that a tolerance provision of 1 per cent on all screen determinations be included in Section 4 and that the words "may be sold" in Section 4 be changed to read "may be marketed." The letter ballot vote of the committee on this recommendation and re-arrangement of the specifications is as follows: Affirmative, 22; negative, 0; not voting, 8.

Tentative Specifications for Gypsum Plasters.—The committee recommends that the following changes be made in the Tentative Specifications for Gypsum Plasters (C 28 - 20 T).[3]

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 609 (1920).

[2] *Ibid.*, p. 612.

[3] *Ibid.*, p. 616.

In the first sentence of Section 2 insert the words "including sand" after "constituent parts." Change all reference to "ready-mixed Gypsum Plaster" in both sub-title and text to "Gypsum Ready-Sanded Plaster" and reference to "Neat Gypsum Plaster" to "Gypsum Neat Plaster" and reference to "Gypsum Wood-Fiber Plaster" to "Gypsum Wood-Fibered Plaster." In Section 14 change the words "may be sold" to read "may be classified." Introduce sections on sampling identical with Sections 5 and 6 of the Tentative Specifications for Calcined Gypsum (C 23 - 20 T). Omit Section 23 on sand and Section 24 on fiber. Make Section 25 on water a footnote.

The committee recommends that the tentative specifications, as thus revised, be submitted to letter ballot of the Society for adoption as standard. The letter ballot vote of the committee on this recommendation is: Affirmative, 18; negative, 3; not voting, 9.

The material included in Section 25 of the Tentative Specifications for Gypsum Plaster, the omission of which is recommended in the previous paragraph, has been incorporated in new Tentative Specifications for Gypsum Plastering Sand appended hereto[1] and are recommended for publication as tentative. The letter ballot vote of the committee on this recommendation is as follows: Affirmative, 20; negative, 4; not voting, 6.

Tentative Specifications for Gypsum Plaster Board.—New specifications for gypsum plaster board have been prepared on the basis of information contained in the 1919 report of this committee and are appended hereto.[2] They have been submitted to letter ballot of the committee for publication as tentative, with the following result: Affirmative, 18; negative, 2; not voting, 10.

Tentative Specifications for Gypsum Wall Board.—New specifications for gypsum wall board have been prepared on the basis of information contained in the 1919 report of this committee and are appended hereto.[3] They have been submitted to letter ballot of the committee for publication as tentative, with the following result: Affirmative, 18; negative, 2; not voting, 10.

Tentative Methods for Tests of Gypsum and Gypsum Products.—The committee recommends that the Tentative Methods for Tests of Gypsum and Gypsum Products (C 26 - 20 T)[4] be revised as follows: Omit Sections 13 to 18 inclusive on microscopic examination. In sub-title VI and in Sections 20, 21, 22, 23, 25, 26, 27 and 28, change the words "normal consistency" to read "testing consistency."

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[1] See p. 559.—ED.

[2] See p. 562.—ED.

[3] See p. 560.—ED.

[4] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 634 (1920).

Amend Section 27 so as to require three briquettes for testing of tensile strength in place of five. The methods as revised were submitted to letter ballot of the committee for adoption as standard, the vote being: Affirmative, 19; negative, 3; not voting, 8. Subsequently, Committee E-1 signified its intention of creating a special sub-committee to discuss certain of these methods. This procedure has been heartily welcomed by Committee C-11 and we therefore recommend that these methods be continued as tentative, in order that Committee E-1 may be given time to act.

By letter ballot of the committee, it was decided to withdraw the present Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 - 16 T).[1] Certain of these definitions have been incorporated in new Tentative Definitions of Terms which are appended hereto[2] and which the committee recommends for publication as tentative. The vote was: Affirmative, 22; negative, 1; not voting, 7.

It is understood by the committee that these will be reviewed during the coming year by Committee E-8.

This report has been submitted to letter ballot of the committee, which consists of 30 members, of whom 23 have voted affirmatively, none negatively, and 7 have refrained from voting.

Respectfully submitted on behalf of the committee,

V. G. MARANI,
Secretary.

WARREN E. EMLEY,
Chairman.

EDITORIAL NOTE.

The Tentative Specifications for Gypsum Plasters as amended were approved at the annual meeting and subsequently adopted by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards.

The proposed revisions of the Tentative Specifications for Gypsum, of the Tentative Specifications for Calcined Gypsum, and of the Tentative Methods of Test for Gypsum and Gypsum Products and of the Tentative Definitions of Terms Relating to the Gypsum Industry were accepted. The tentative standards as thus revised appear on pages 553–558 and 590–601.

The proposed Tentative Specifications for Gypsum Plaster Board, the proposed Tentative Specifications for Gypsum Wall Board and the proposed Tentative Specifications for Gypsum Plastering Sand were accepted for publication as tentative and appear on pages 559–564.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 658 (1920).

[2] See p. 600.—ED.

REPORT OF COMMITTEE D-1

ON

PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS.

Committee D-1 on Preservative Coatings for Structural Materials has held two meetings during the past year. At the first meeting held in Philadelphia on November 20, 1920, a general reorganization of the sub-committees was effected and a number of other important matters was considered, the most important being a report from the Advisory Committee recommending that Sub-Committee XX on Tung Oil be combined with Sub-Committee III on Testing of Paint Vehicles under the title of Sub-Committee III on Testing of Paint Vehicles, and in recommending that Sub-Committee XIII be abolished and that any further activities be handled by Sub-Committee IX. Several other sub-committees were discontinued for the present.

On March 22, 1921, the second meeting was also held in Philadelphia, there being a goodly proportion of the members in attendance, while excuses were received from most of those who were unable to be present.

Following the suggestion of the Advisory Committee it was agreed that definite dates should be fixed for the fall and spring meetings. The dates decided upon were the first Tuesday in October and the first Tuesday in April.

The secretary read an announcement from the Federated Amercan Engineering Societies, outlining the scope and membership of that organization and inviting the American Society for Testing Materials to become a charter member. A resolution was adopted to the effect that, because a large proportion of the members of the American Society for Testing Materials are also members of other engineering societies already or soon to become charter members of the Federated American Engineering Societies, and because the work of the American Society for Testing Materials is not, to any great extent, along the lines of the activities of the Federated American Engineering Societies, Committee D-1 deems it inadvisable for the American Society for Testing Materials to accept the invitation extended.

The reports of the following sub-committees are appended, many of them containing recommendations in regard to standards and tentative standards:

Sub-Committee III on Testing of Paint Vehicles, including a tentative revision of the Standard Specifications for Purity of Raw Tung Oil.

Sub-Committee V on Linseed Oil, including submission of Tentative Specifications for Purity of Raw Linseed Oil from South American Seed, and Tentative Specifications for Purity of Boiled Linseed Oil from South American Seed.

Sub-Committee VI on Definitions of Terms used in Paint Specifications, including definitions.

Sub-Committee XI on Paint Thinners Other Than Turpentine, including a revision of the Standard Method for Determining Flash Point of Volatile Paint Thinners, and approval of new Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products, recommended in the Report of Committee D-2, and recommendation for the withdrawal of present Standard Tests for Paint Thinners Other Than Turpentine if and when the new distillation method is accepted by the Society.

Sub-Committee XII on Turpentine, including:
Revised Standard Specifications for Turpentine.

Sub-Committee XIV on Preparation of Iron and Steel Surfaces for Painting.

Sub-Committee XV on Specifications for Pigments Dry and in Oil when Marketed in that Form, including Tentative Specifications for:

Zinc Oxide;
Leaded Zinc Oxide;
Basic Carbonate White Lead;
Basic Sulfate White Lead;
Red Lead;
Iron Oxide and Iron Hydroxide;
Ochre.

These sub-committee reports, together with the recommendations, have been submitted to letter ballot, the vote contained therein being as follows:

	AFFIRMATIVE	NEGATIVE	NOT VOTING.
General Report	35	..	18
Report of Sub-Committee III on Testing of Paint Vehicles, including a tentative revision of the Standard Specifications for Purity of Raw Tung Oil (D 12 - 16)	42	1	10

	AFFIRMATIVE	NEGATIVE	NOT VOTING
Report of Sub-Committee V on Linseed Oil, including:			
Tentative Specifications for Purity of Raw Linseed Oil from South American Seed	44	..	9
Tentative Specifications for Purity of Boiled Linseed Oil from South American Seed	38	1	14
Report of Sub-Committee VI on Definitions of Terms used in Paint Specifications, including definitions of:			
Size	38	6	9
Varnish	40	6	7
Enamel	41	5	7
Filler	45	1	7
Toner	42	2	9
Lake	44	1	8
Drying Oil	46	..	7
Semi-Drying Oil	46	..	7
Non-Drying Oil	45	1	7
Report of Sub-Committee XI on Paint Thinners other than Turpentine, including:			
Revision of the Standard Test for Flash Point of Volatile Paint Thinners (D 56 – 19)	45	3	5
Approval of new Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and similar Petroleum Products, recommended in annual report of Committee D-2, and withdrawal of present Standard Tests for Paint Thinners Other Than Turpentine if and when the new distillation method is accepted by the Society	43	3	7
Report of Sub-Committee XII on Turpentine, including:			
Advancement of Tentative Specifications for Turpentine to Standard	47	1	5
Report of Sub-Committee XIV on Preparation of Iron and Steel Surfaces for Painting	43	..	10
Report of Sub-Committee XV on Specifications for Pigments Dry and in Oil when Marketed in That Form, including Tentative Specifications for:			
Zinc Oxide	43	1	9
Leaded Zinc Oxide	41	2	10
Basic Carbonate White Lead	40	3	10
Basic Sulfate White Lead	42	1	10
Red Lead	40	2	11
Iron Oxide and Iron Hydroxide	40	2	11
Ochre	41	1	11

Respectfully submitted on behalf of the committee,

ALLEN ROGERS,
Chairman.

R. L. HALLETT,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Purity of Raw Tung Oil were accepted for publication as tentative and appear on pages 835–837.

The proposed revision of the Standard Test for Flash Point of Volatile Paint Thinners was approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The method of test as thus revised appears in the 1921 Book of A.S.T.M. Standards.

The nine proposed tentative specifications referred to in this report and the proposed Tentative Definitions of Terms Relating to Paint Specifications were accepted for publication as tentative and appear on pages 613–630.

The recommendation contained in the report that the Tentative Specifications for Turpentine as amended be advanced to standard to replace the Standard Specifications for Turpentine was approved at the annual meeting and referred to letter ballot of the Society. In view of the withdrawal of the Standard Tests for Paint Thinners other than Turpentine which are referred to in the tentative specifications, Committee D-1, subsequent to the annual meeting, recommended to the Executive Committee that the action taken at the annual meeting in regard to the advancing of the tentative specifications to standard be reversed. As a result of a second letter ballot, canvassed September 15, 1921, the standard specifications were withdrawn and the tentative specifications were retained as tentative and appear on pages 604–612 in their revised form.

REPORT OF SUB-COMMITTEE III ON TESTING OF PAINT VEHICLES.

New Work Proposed.—There is being forwarded to the working members of the reorganized Sub-Committee III a series of oils for experimental work during the coming year. The samples will include sunflower-seed oil, china-seed oil, perilla oil, rubber-seed oil, and American and foreign tung oils. The investigations will include:

Analysis.
Determination of the value of the Hanus vs. the Wijs iodine method.
Effect of heating and blowing.
Effect of various driers.
Individual research problems, as suggested by the various members.

It is believed that much important information will be developed as a result of these tests, and inasmuch as the members of the committee will have a period of nearly a year to work upon the samples before making reports, it is hoped that the results obtained will be of much interest to the committee.

Specifications for Purity of Raw Tung Oil.—Because tests have shown that the amount of free fatty acid present in tung oil has a marked influence on the heating test, it is recommended that the Standard Specifications for Purity of Raw Tung Oil (D 12 - 16),[1] as amended by the present published tentative revision,[2] be further revised by inserting the following paragraph after the heading "Heating Test:"

> "Preparation of Sample for Heating Test—Five grams of hydrated lime, $Ca(OH)_2$, (at least 72 per cent CaO) shall be added to 100 cc. of tung oil. The mass shall be stirred at intervals for fifteen minutes and then filtered through a quantitative ribbed filter paper. The funnel should be covered with a watch glass. The oil so obtained shall then be submitted to the heat test."

With this further change it is recommended that the tentative revision be continued as tentative.

Respectfully submitted on behalf of the sub-committee,

H. A. Gardner,
Chairman.

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[1] 1918 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 819 (1920).

REPORT OF SUB-COMMITTEE V ON LINSEED OIL.

The objects sought by this committee when outlining the work herein reported were:

First, to secure additional analytical data upon oil from South American flaxseed, in order that we might sufficiently increase the number of samples to warrant the basing of a specification upon the compiled results;

Second, to make a comparison between the Hanus and Wijs methods for the determination of the iodine number of linseed oil;

Third, to apply the Steele-Washburn method for the determination of the percentage of insoluble hexabromides to several oils by different operators;

Fourth, to compare the effect of pre-heating the linseed oil previous to making the foots determination on it;

Fifth, to analyze a sample of oil from Manchurian flaxseed to determine its constants.

The history of the samples submitted is as follows:

Number 42.—Raw Linseed oil, from Chinese flaxseed grown in Manchuria during the year 1916. Sample taken at the plant of the Toledo Seed and Oil Co., Toledo, Ohio, on July 24, 1917, by G. H. Pickard. Made by hot hydraulic pressure. Kept in a sealed tin can until June 11, 1920, when it was bottled by G. H. Pickard.

Number 43.—Raw Linseed oil, from South American flaxseed of the Argentine 1918–19 crop. Made at the Edgewater, New Jersey, plant of the Midland Linseed Products Co., by hot hydraulic pressure. Sample taken by John Gottlemen, Foreman, June 24, 1919. Kept in a sealed tin can until bottled February 5, 1920, by G. H. Pickard.

Number 44.—Raw Linseed oil, from South American flaxseed of the Argentine 1918–19 crop. Made at the Buffalo, New York, plant of the Archer-Daniels Linseed Co., by hot hydraulic pressure, twice filtered through cloth. Sample taken by George Brown, Assistant Superintendent, June 24, 1919. Kept in a sealed tin can until February 6, 1920, when bottled by G. H. Pickard.

Number 45.—Raw Linseed oil, from South American flaxseed of the Argentine 1918–19 crop. Made at the Brooklyn, New York, plant of the National Lead Co. during the first two weeks of May, 1919. Sample taken May 15, 1919, by W. J. Muesch, Superintendent. Kept in a sealed tin can until bottled February 9, 1920, by G. H. Pickard.

Number 46.—Raw Linseed oil, reported to be from South American flaxseed of the Argentine 1918–19 crop. Made at the Staten Island plant of the American Linseed Co., by hot hydraulic pressure. Sample taken August 7, 1919, by M. O. Tietze, Manager. Bottled February 23, 1920.

NOTE.—The analytical constants of this oil are considerably beyond the range established for South American seed. Obviously, in spite of our care, a mistake was made in drawing this sample. It probably is oil from North American seed. The results obtained are not used in any averages.

These samples were sent to all of the members of the committee. Those reporting are as follows:

No. 1.—Experimental Station, E. I. du Pont de Nemours and Co., Henry Clay, Delaware, represented by Doctor Eliot Booge.
No. 2.—L. L. Steele, Bureau of Standards, Department of Commerce, Washington, D. C.
No. 3.—Congoleum Co., Marcus Hook, Pa., represented by R. D. Bonney.
No. 4.—Glenn H. Pickard, 9 South Clinton Street, Chicago, Ill.
No. 5.—D. A. Kohr, Lowe Brothers Co., Dayton, Ohio.
No. 6.—C. B. Mills, National Lead Co., 129 York Street, Brooklyn, New York.

METHODS OF ANALYSIS.

The methods of analysis employed were those given under Standard Specifications for North American Linseed Oil (Serial Designation: D 1 - 16). The method for the foots determination was that under Tentative Specifications for Foots Permissible in Properly Clarified Pure Raw Linseed Oil from North American Seed (Serial Designation: D 51 - 18 T). In addition to the method therein outlined, one portion of the oil was to be heated to 150° F., allowed to cool to room temperature, and then the method as directed applied. The determination of the hexabromide number was to be made by the Steele-Washburn method, directions for which are found in the Journal of Industrial and Engineering Chemistry, Vol. 12, p. 52, January, 1920. The method for the determination of the iodine number by the Wijs method is that recommended by the Committee on the Analysis of Commercial Fats and Oils of the American Chemical Society, published in the Journal of Industrial and Engineering Chemistry, Vol. 10, No. 4, p. 315, April, 1918. The results are given in the accompanying tables.

COMPARISONS OF HANUS AND WIJS METHODS FOR THE DETERMINATION OF THE IODINE NUMBER.

In comparing the results obtained by the use of these two methods for the determination of the iodine absorption of linseed oil, one of the important items to be considered is the difference between the results by the two methods on each of the several oils analyzed. In the following table will be found these differences:

TABLE I.—CONSTANTS OF SOUTH AMERICAN RAW LINSEED OILS.

Analyst.	Specific Gravity	Iodine No.		Saponification No.	Acid No.	Refractive Index.	Hexabromide, per cent.	Foots, per cent.	
		Hanus.	Wijs.					As received.	Heated to 150° F.
RAW OIL NUMBER 43.									
1	0.9327	178.4	182.6	192.3	2.6	1.4782	46.06	0.6	0.8
2	0.9327	177.7	182.6	193.9	2.4	1.4796	45.80	0.5	0.0
3	0.9320	.....	181.9	192.1	3.1	......	.....	1.0	0.8
4	0.9329	178.0	182.9	191.6	2.9	1.4784	45.92	0.6	0.6
5	0.9340	175.0	181.0	.....	3.0	......	.....	3.0	...
6	0.9330	176.7	181.1	190.6	2.8	......	49.56	1.3	...
Average	0.9329	177.3	182.0	192.1	2.8	1.4787	46.83	1.16	0.55
RAW OIL NUMBER 44									
1	0.9328	179.3	182.9	192.9	3.1	1.4783	45.99	1.6	0.4
2	0.9325	178.4	183.0	195.0	3.0	1.4795	46.3	0.0	0.0
3	0.9332	.....	181.8	191.7	3.3	......	.....	1.2	1.2
4	0.9325	178.5	182.5	192.6	3.4	1.4784	47.05	0.4	0.2
5	0.9340	176.0	182.0	.....	3.4	......	.....	2.0	...
6	0.9330	176.7	181.2	190.7	3.3	......	49.85	1.2	...
Average...	0.9330	177.8	182.2	192.6	3.3	1.4787	47.29	1.06	0.45
RAW OIL NUMBER 45.									
1	0.9338	181.4	185.7	192.7	2.2	1.4788	43.26	0.4	0.4
2	0.9333	181.2	185.6	193.2	2.3	1.4797	46.6	0.0	0.0
3	0.9327	.....	184.4	191.6	2.4	......	.....	0.6	0.2
4	0.9331	181.3	186.3	191.8	2.5	1.4789	46.82	0.8	0.8
5	0.9350	178.0	184.0	.....	2.6	......	.....	2.0	...
6	0.9340	180.1	183.9	190.8	2.4	......	51.02	0.8	...
Average...	0.9336	180.4	185.0	192.0	2.4	1.4791	46.92	0.76	0.35

TABLE II.—CONSTANTS OF OTHER RAW LINSEED OILS.

Analyst.	Specific Gravity.	Iodine No.		Saponification No.	Acid No.	Refractive Index.	Hexabromide, per cent.	Foots, per cent.	
		Hanus.	Wijs.					As received.	Heated to 150° F.
RAW OIL NUMBER 42 From Chinese Flaxseed.									
1	0.9339	184.1	187.8	192.9	1.7	1.4784	46.88	1.6	0.4
2	0.9337	183.7	188.9	193.8	1.7	1.4799	47.6	0.0	0.0
3	0.9332	.....	186.9	192.1	2.0	......	.....	1.2	0.4
4	0.9334	183.4	188.0	192.1	1.8	1.4792	49.49	0.8	0.0
5	0.9350	181.0	187.0	.....	2.1	......	.....	2.5	...
6	0.9341	182.7	187.0	190.6	1.9	......	52.1	1.2	...
Average...	0.9339	183.0	187.6	192.3	1.87	1.4792	49.04	1.21	0.2
RAW OIL NUMBER 46. Apparently from North American Flaxseed.									
1	0.9342	186.2	190.5	192.5	3.3	1.4789	44.76	0.4	0.4
2	0.9343	186.1	190.5	194.0	3.1	1.4796	46.6	0.0	0.0
3	0.9337	.....	188.5	191.6	3.8	......	.....	0.8	0.4
4	0.9336	186.6	190.6	193.4	3.6	1.4791	48.49	0.0	0.0
5	0.936	183.0	188.0	.....	3.0	......	.....	2.0	...
6	0.9345	184.7	188.5	191.0	3.5	......	51.45	0.5	...
Average...	0.9344	185.3	189.4	192.5	3.35	1.4792	47.83	0.61	0.2

	WIJS.	HANUS.	DIFFERENCE.
Oil Number 42	187.6	183.0	4.6
" " 43	182.0	177.3	4.7
" " 44	182.2	177.8	4.4
" " 45	185.0	180.4	4.6
" " 46	189.4	185.3	4.1
Average			4.48

This average difference of 4.5 per cent of iodine absorbed appears, from these figures, to be close to what might be expected when using the two methods on the same oils. It is interesting, also, to note the concordance of these differences, for from the highest to the lowest there is but a 0.6-per-cent spread. More data should be secured to substantiate this differential, for if it is as constant as it appears it would be easy to change specifications for the iodine number by simply adding this differential to the established Hanus figure.

In studying these two methods, another item of interest is the concordance of the results obtained by various operators with each of the two methods on the same oil. In the following table are set forth the differences between the highest and lowest results reported by the five operators.

	HIGHEST TO LOWEST.	
	HANUS.	WIJS.
Oil Number 42	3.6	1.6
" " 43	3.4	1.9
" " 44	3.3	1.8
" " 45	3.4	2.4
" " 46	3.1	1.9
Average	3.36	1.9

By these averages, the balance is shown to be in favor of the Wijs method. The fact, however, that operator No. 5 is consistently lower by the Hanus method than the others must not be overlooked. If his results are omitted, the average difference between the highest and lowest results of the other four is 1.78 by the Hanus method, thus putting it on a par with the Wijs method for accuracy.

In forming an opinion of the relative accuracy of the two methods, however, we believe that all results ought to be considered.

In the following table are shown the differences by each of these methods between the average and the highest result and the average and the lowest result.

	HIGHEST TO AVERAGE.		LOWEST TO AVERAGE.	
	HANUS.	WIJS.	HANUS.	WIJS.
Oil Number 42	1.1	1.3	2.0	0.6
" " 43	1.1	0.9	2.3	1.0
" " 44	1.5	0.8	1.8	1.0
" " 45	1.0	1.3	2.4	1.1
" " 46	1.3	1.2	2.3	1.4
Average	1.18	1.10	2.16	1.02

In studying these results, we find no appreciable difference between the two methods, except in the case of the Hanus lowest to average column. This can be accounted for by the results of Analyst No. 5.

CONCLUSIONS.

From these data your committee concludes:

That further work would probably result in the establishment of a fixed differential, which could be added to Hanus iodine values to convert them to Wijs values, thus making simple the revision of specifications containing Hanus figures;

That the accuracy of the Wijs solution is slightly greater than that of the Hanus;

That the preparation of the two solutions represents about the same amount of labor, especially when, in the Hanus solution, a perfect balance between iodine and bromine is made;

That the time required to complete the reaction is shorter with the Wijs than with the Hanus solution;

That because the Wijs solution only can be used in determining satisfactorily the iodine absorption of shellac and of China wood oil it is a more generally useful solution than is the Hanus, for if the Hanus solution is employed for linseed oil, those laboratories in which analyses of linseed and China wood oils and of shellac are made would require to have the two solutions, whereas if the Wijs solution was employed, it alone would be necessary.

RECOMMENDATIONS.

Your committee recommends that either more work be done to establish, with greater certainty, the differential existing between the results obtained by the Hanus and Wijs methods for the determination of the iodine number of linseed oil to the end that our present specifications can be so altered that the Wijs method will replace the Hanus method; or, that samples sufficient to establish the Wijs iodine number for linseed oil be secured and analyzed, and the limits of the iodine number be thus determined. With the data thus secured the Wijs method would be recommended as optional.

DISCUSSION OF FOOTS DETERMINATION.

The results obtained by the use of the prescribed method for the determination of the percentage of foots in raw linseed oil show a considerable difference between the extremes, which in one case is from 0 to 2.5 and in another from 0.5 to 3.0. The application of heat to the oil previous to making the determination seems to result in closer agreement between different operators. We believe, therefore, that the modification warrants further study. In view of this fact, your committee recommends that the present specification of 2 per cent be continued as tentative, while the committee further investigates the effect of the pre-heating of the oil.

DISCUSSION OF THE RESULTS OF THE DETERMINATION OF THE HEXABROMIDE NUMBER BY THE STEELE-WASHBURN METHOD.

In the first two tables we have the results obtained by four different operators on five samples of oil, the percentage of insoluble hexabromides of which were determined by the Steele-Washburn method. The results show that while the method is undoubtedly more accurate than any one yet proposed for the making of this determination, still the range between results obtained by four operators is rather wide. In the following table the difference between the highest and the lowest of the individual results is given:

Oil Number 42	5.22 per cent
" " 43	3.76 "
" " 44	3.86 "
" " 45	7.82 "
" " 46	6.69 "

There is doubt in the minds of your committee as to what action should be taken in this matter, for the method is undoubtedly a valuable one, and yet the concordance of the results does not seem sufficiently great to warrant the insertion, at this time, of limits for the percentage of insoluble hexabromides in our specifications for raw linseed oil. Your committee recommends that further work be done upon the determination of the percentage of insoluble hexabromides in linseed oil.

OIL FROM CHINESE FLAXSEED.

From the analysis of this one sample, Number 42, it appears that oil from Manchurian flaxseed has just about the same constants as those of North American linseed oil. This is to be expected, due to the relatively close relation between the climates of the portion of Manchuria where the flaxseed is raised and that of our own Northwest. This meager data is insufficient to warrant the inclusion of oil from Chinese flaxseed under our specifications for North American linseed oil, but is of interest in the general study of linseed oil.

RAW OILS FROM SOUTH AMERICAN FLAXSEED.

In the following table are set forth the data obtained from all of the samples of oil from South American flaxseed which have been examined by your committee:

TABLE III.—CONSTANTS OF OIL FROM SOUTH AMERICAN SEED.

Oil No.	Specific Gravity at 15° 5/ 15°.5C.	Iodine No.		Acid No.	Saponification No.	Percentage Unsaponifiable.	Refractive Index at 25° C.	Hexabromides, per cent.	Foots, per cent.	
		Hanus.	Wijs.						As received.	Heated to 150° F.
16........	0.9319	172.4	.....	1.24	190.5	1.05	1.4779	.....	....	....
23........	0.9324	172.3	.....	3.54	190.5	....	1.4784	.....	....	....
36........	0.9329	179.2	.....	5.48	192.4	1.15	1.4796	50.03[*]	....	....
37........	0.9333	179.0	.....	6.34	191.4	1.00	1.4795	48.80[*]	....	....
38........	0.9334	180.3	.....	3.91	190.5	1.05	1.4796	49.64[*]	....	....
43........	0.9329	177.3	182.0	2.8	192.1	....	1.4787	46.83	1.16	0.55
44........	0.9330	177.8	182.2	3.3	192.6	....	1.4787	47.29	1.06	0.45
45........	0.9336	180.4	185.0	2.4	192.0	....	1.4791	46.92	0.76	0.35
Average...	0.9329	177.3	183.1	3.63	191.5	1.06	1.4789	47.01	0.99	0.45
High......	0.9336	180.4	185.0	6.34	192.6	1.15	1.4796	47.29	1.16	0.55
Low......	0.9319	172.3	182.0	1.24	190.5	1.00	1.4779	46.83	0.76	0.35

[*] Eibner.

Your committee feels that it has examined a sufficient number of samples of raw linseed oil from South American seed to warrant the recommendation of specifications for that oil for tentative adoption. Your committee, therefore, submits the appended specifications[1] for your consideration.

BOILED LINSEED OIL FROM SOUTH AMERICAN SEED.

Inasmuch as oil from South American flaxseed is, in the manufacture of boiled oil, accorded the same treatment as oil from North American flaxseed the same differences would be caused in the physical and chemical properties of both oils when boiled oil is made from raw oil. This statement is substantiated by the results obtained by the committee in its analysis of oils Numbers 39, 40 and 41, which are boiled linseed oils made from raw oil from South American seed.

It, therefore, seems to your committee proper to recommend at this time, for tentative publication, specifications for boiled linseed oil from South American seed, which shall differ from the specification for raw linseed oil from the same source to the same extent in each comparable item as do the two specifications for oil from North American seed.

Your committee, therefore, recommends for acceptance the appended specifications[2] for Purity of Boiled Linseed Oil from South American Seed:

Respectfully submitted on behalf of the sub-committee,

GLENN H. PICKARD, *Chairman.*

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[1] See p. 613.—ED.

See p. 614.—ED.

REPORT OF SUB-COMMITTEE VI ON DEFINITIONS OF TERMS USED IN PAINT SPECIFICATIONS.

At the meeting of Committee D-1 held March 27, 1921, a report was presented on a number of terms used in paint specifications. The sub-committee has given consideration first of all to these definitions and changes in them which were suggested by a number of members of D-1. The sub-committee recommends that these definitions be accepted for publication as tentative in the revised form given in the appended Tentative Definitions of Terms Relating to Paint Specifications.[1]

The sub-committee suggests that members of Committee D-1 submit to it for its consideration, terms which they believe should be defined.

Respectfully submitted on behalf of the sub-committee,

L. P. NEMZEK,
Chairman.

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[1] See p. 629.—ED.

REPORT OF SUB-COMMITTEE XI ON PAINT THINNERS OTHER THAN TURPENTINE.

A revision of the present Standard Test for Flash Point of Volatile Paint Thinners (D 56 – 19)[1] has been made by Sub-Committee XI in cooperation with Sub-Committee XII and Committee D-2. The title of the revised method has been changed to read Standard Method of Test for Flash Point of Volatile Flammable Liquids, in order to broaden its scope, because this method has been adopted by the National Fire Protection Association for testing all flammable liquids. The revision is attached to this report and is recommended for adoption as standard.

Committee D-2, in cooperation with Sub-Committee XI and Sub-Committee XII of Committee D-1, has drawn up a new method of distillation entitled Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products. This new distillation method is included in the annual report of Committee D-2 with the recommendation that it be accepted as tentative. Sub-Committee XI believes that this new distillation method should be accepted, and recommends that it be approved by Committee D-1 and that the present Standard Tests for Paint Thinners Other Than Turpentine (D 28 – 17) be withdrawn if and when the new tentative method is accepted by the Society.

Respectfully submitted on behalf of the sub-committee,

CLOYD M. CHAPMAN,
Chairman.

REVISION OF THE STANDARD TEST FOR FLASH POINT OF VOLATILE PAINT THINNERS.

The committee recommends the following revisions to be made in the Standard Test for Flash Point of Volatile Paint Thinners (D 56 – 19):[2]

1. Change the title from its present form: namely,

"Standard Test for Flash Point of Volatile Paint Thinners"

to read as follows:

"Standard Method of Test for Flash Point of Volatile Flammable Liquids."

2. *Section 1.*—In place of the present Section 1 substitute the following:

"(*a*) The Tag Closed Tester shall be used for all volatile flammable liquids flashing below 175° F. with the exception of products classed as Fuel Oil. Determination of the flash point of fuel oil by the Tag Tester is permissible, but the Pensky-Martens Tester is to be preferred.

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[1] 1918 Book of A.S.T.M. Standards.

[2] A.S.T.M. Standards adopted in 1919.

"(*b*) The Tag Closed Tester shall conform to the following dimensions within the limits of tolerances given:

DIMENSION.	NORMAL.	TOLERANCES.
Depth of water surface below top of cup, in.	$1\frac{3}{32}$ (27.8 mm.)	$\pm\frac{1}{64}$ (0.4 mm.)
Depth of oil surface below top of cup, in.	$1\frac{5}{32}$ (29.4 mm.)	$\pm\frac{1}{64}$ (0.4 mm.)
Depth of top of bulb of oil thermometer when in place below top of cup, in.	$1\frac{5}{16}$ (33.3 mm.)	$\pm\frac{1}{32}$ (0.8 mm.)
Inside diameter of oil cup at top, in.	$2\frac{1}{8}$ (54.0 mm.)	$\pm$0.005 (0.1 mm.)
Weight of oil cup, g.	68	$\pm$1
Diameter of bead on top of cover, in.	$\frac{5}{32}$ (4.0 mm.)	$\pm\frac{1}{64}$ (0.4 mm.)

The plane of underside of cover to be between the top and bottom of the burner tip when the latter is fully depressed.

Specifications for Thermometer.

The Thermometer shall conform to the following specifications:

Type: Etched stem glass.

Total length: 275 mm.

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.

Bulb: Corning Normal, Jena 16 III or equally suitable thermometric glass. Diameter less than stem, length 9 to 13 mm.

Actuating liquid: Mercury.

Range: 20° F. to 230° F.

Immersion: $2\frac{1}{4}$ in. (57 mm.) from end of bulb. Words "$2\frac{1}{4}$-in. immersion" etched on the stem, also a line around the stem to indicate depth of immersion.

Distance to 20° line from bottom of bulb: 75 to 90 mm.

Distance to 230° line from top of stem: 25 to 40 mm.

Expansion chamber: Required.

Filled: Nitrogen Gas.

Top finish: Glass Ring.

Graduation: All lines, figures and letters clear cut and distinct. Scale graduated in 1° divisions. Scale numbered every 10°, the first and each succeeding 5° line to be longer than the others.

Special marking:[1] "A.S.T.M. P.M. and Tag," serial number, manufacturer's name or trade mark etched on the stem.

Accuracy: Error at any point in scale shall not exceed 1° F.

Points to be tested: 32°, 100°, 150°, 212° F."

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[1] This thermometer is identical with the low range instrument specified for use with the A.S.T.M. Pensky-Martens Closed Tester.

REPORT OF SUB-COMMITTEE XII ON TURPENTINE.

Several of the manufacturers of wood turpentine, using the steam solvent process, have claimed that the minimum refractive index 1.468 of the Standard Specifications for Turpentine (D 13 - 15)[1] and Tentative Specifications for Turpentine (D 13 - 20 T)[2] is too high for turpentine produced by the steam solvent process and have asked that the limit be lowered to admit wood turpentine made by the steam solvent process as now conducted.

The Bureau of Chemistry, Department of Agriculture, has recently examined 26 samples representing the product of six makers of steam solvent wood turpentine, in fact of all the chief producers of this product, and finds that the refractive index at 20° C. of these samples falls between 1.4652 and 1.47, and by far the greater number fall between 1.466 and 1.468.

The polymerization residue of these 26 samples varies from 0.8 to 2.6 per cent. Most of them fall between 1.5 and 2.5 per cent.

The refractive index at 20° C. of the polymerization residue falls between 1.473 and 1.5.

Since light mineral oil is used in the steam solvent process of producing wood turpentine and wood rosin, it follows that wood turpentine made by the steam solvent process almost invariably contains a small percentage, from 1 to 2 per cent, of mineral oil and hence the refractive index of the polymerization residue is always lower and may be much lower than the refractive index of the residue of an unadulterated gum turpentine.

In view of these facts, the sub-committee recommends that the specifications for gum turpentine remain in their present form but that the minimum refractive index for wood turpentine be made 1.465 and that the minimum refractive index for the polymerization residue of wood turpentine be made 1.48, and that with these changes the tentative specifications be submitted to letter ballot for adoption as standard.

Respectfully submitted on behalf of the sub-committee,

F. P. Veitch,
Chairman.

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[1] 1918 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Test. Mat., Vol. XX, Part I, p. 680 (1920).

REPORT OF SUB-COMMITTEE XIV ON PREPARATION OF IRON AND STEEL SURFACES FOR PAINTING.

Sub-Committee XIV on the Preparation of Iron and Steel Surfaces for Painting submits herewith a report on the inspections of the test panels at Altoona, Pa., and Brooklyn, N. Y., made October 26–27, 1920. This report has been prepared so as to show for each test panel, opposite a description of the same, the condition as found at the inspection made in 1920.

A general résumé of the test data and statement of the general condition of the test panels at the time of last inspection (October 26–27, 1920) follows:

Thirty-two plates of old and new $\frac{1}{8}$-in. car steel were prepared in duplicate for 16 different conditions of surface (including the effects of surrounding atmospheric variations of temperature and humidity at time of painting) and were painted on one side with two coats of iron oxide paint. One set of 16 plates was exposed to the weather on a railroad shop roof at Altoona, Pa., the other on a factory roof at Brooklyn, N. Y., both sets being exposed on February 9, 1917.

Inspections were made by members of the sub-committee in February, 1918, February, 1919, and October, 1920.

All test data are given in detail in the report of the sub-committee published in the Proceedings of the Society, Vol. XVII, Part I, p. 451, (1917).

At the time of last inspection the test surfaces of all tests at Altoona, with the exception of those of test No. 10, were very fully protected with the paint coatings, which showed very little deterioration. The paint coatings of the tests at Brooklyn had deteriorated much more than those at Altoona, with a rather wide range in condition on different plates, test No. 10 being in far the worst condition. It was estimated that several more years' exposure would be required for the coatings at Altoona (with the exception of test No. 10) to deteriorate to the degree that might be considered as the point of failure, while a number of those at Brooklyn would probably reach that point by the end of another year. The tests at each place show results that are, in general, comparatively consistent.

While the tests are not completed and final conclusions are not offered at this time, there are certain indications that are matters of such importance that it seems desirable to report them. These are the following:

1. The thorough methods of preparation, *i.e.*, sand blasting and

pickling, show no superiority in general over ordinary methods of cleaning the surface by scraping, wire brushing and wiping, where corrosion has not commenced or has only moderately advanced. This applies to both new steel and old steel which has been in service. Test No. 10 indicates that where corrosion has advanced greatly, ordinary methods do not give satisfactory results.

2. Weathering to permit loosening and partial removing of mill scale, with ordinary methods of cleaning before painting, is detrimental to preservation.

3. Painting in a cold dry atmosphere results in preservation as good as painting in warm dry atmosphere, or on heated steel. (This may be due to the greater thickness of coatings applied in the cold atmosphere. See spreading record of coatings.) The appearance of the coating may be impaired by shrivelling and wrinkling.

4. That sand blast cleaning may give better results than pickling is indicated by the panels exposed at Brooklyn. There is no appreciable difference observable in the panels treated by the two methods and exposed at Altoona.

5. The exposure of sand blasted and pickled surfaces for the development of incipient rusting before painting may be detrimental rather than beneficial as indicated by the results of test of pickled plate at Brooklyn.

6. The preparation of old painted steel surfaces which have bare rusted spots, by brush coating with benzine over and around the rust spots, burning the benzine off and then scraping and wire brushing, gives better results than scraping and wire brushing without the benzine treatment. Where any considerable amount of surface requires treatment, the comparative cost of the method and of sand blasting should be considered.

7. There is no difference observable in the results of the application of the same methods to old and to new steel.

While these tests were intended to represent service conditions, and do so to a great extent, they have some limitations in that respect. The panels were subject to no strains, vibrations, or shocks. Those shipped to Brooklyn suffered some mechanical injury, which, however, did not have any apparent effect on the tests. The steel surfaces, while normal and ordinary for steel car sheets, were perhaps rolled smoother and possibly rolled so as to produce greater adherence in the mill scale than in case of rolled shapes or some thicker plates; however, this could hardly have had much effect in the cases where the mill scale was partly removed before painting.

The sub-committee has under consideration the question as to the effect of the absence of strain, vibration and shock, and may submit further comments or recommendations to the committee in a subsequent report.

Respecfully submitted on behalf of the sub-committee,

A. W. Carpenter,
Chairman.

APPENDIX

REPORT OF INSPECTION OF TEST PANELS, OCTOBER, 1920

PLATES PAINTED IN JANUARY, 1917; EXPOSED IN FEBRUARY, 1917

Test No.	Description.	Condition at Altoona, Pa., October 26, 1920.	Condition at Brooklyn, N. Y., October 27, 1920.
		SERIES A.—TESTS ON NEW STEEL	
1	Plates painted as received from mill; surfaces clean and free from rust, mill scale intact. Paint applied in warm, dry room.	Generally excellent. A very few rust pits along edges and a pair about 4 in. from bottom and 4 in. from center line. A line of surface spots about ¼ in. in average diameter across plate about 3 in. from bottom similar to those on No. 3 and others. Edges all around show darker color than body for ½ to 2 in. wide and some heavy corrosion on extreme edges.	Very good general condition, similar to last inspection except pin-head rust spots have enlarged, and a few new pin-head spots and about half dozen larger ones, all scattered, have developed. Surface streaked with dark lines along brush marks—these removable with soap and water. Comparative rating, 90 per cent.
2	Test surface rather badly abraded, about 25 per cent of mill scale gone, slightly rusted, also, smeared with tallow, washed with benzine, scraped and wire-brushed. Painted in warm room.	Generally the same as No. 1. Some surface spots as on No. 1, some in a horizontal line across left half of plate about 3 in. from top, others scattered, mainly over left end. Darker color and corrosion on edges as on No. 1.	Rust spots of last inspection enlarged up to ½ in. in diameter. A group of rust spots over area 4 by 16 in. along center of plate and another smaller group midway towards left edge. Badly spotted with rust on four corners. Rated 70 per cent.
3	Surfaces sand-blasted and painted immediately thereafter in warm, dry room.	Coating intact and smooth. Entire surface mottled with spots of darker color than main surface. These spots were found to be removable from coating by vigorous washing with sponge, soap and water. No apparent corrosion under spots where the coating was cut off for inspection. Darker color around edges than on No. 1 but fewer rust pits and less extreme edge corrosion.	Same as last year. Apparently about same number of rust spots as last inspection but spots greatly enlarged (up to ¼ in. in diameter over center of plate). Top and bottom edges worse than No. 2 which may be due to mechanical injuries. Rated 70 per cent.
4	Surfaces sand-blasted and heated immediately thereafter in an oven to 225° F. Painted while still warm.	Coating intact and smooth. Entire surface mottled with spots similar to No. 3 but more numerous —few spots more than ¼ in. apart. Dark streaks along brush marks. Spots removable with soap and water. Edges as on No. 3.	Surface away from edges worse than No. 3, with top and bottom edges about the same. Pin-head spots of previous inspection enlarged and many new ones developed, especially over upper half and upper left side. Rated 50 per cent.
5	Surfaces sand-blasted and placed in cool, damp room for 40 minutes and painted therein. Temperature when painted 43 to 44° F.	Surface intact and smooth and generally like Nos. 1 and 2 but with surface spots more numerous and more scattered. Edges about the same as Nos. 3 and 4. Granular spots noted in 1918 not now noticeable.	Breaks in coating across upper 10 in. enlarged, many to ½ in. wide. A group of rust spots 10 in. from base and 8 in. from left side, average ½ in. in diameter, many continuous. A few other scattered ¼-in. spots. Rated 50 per cent.
6	Plates as received from mill; sand-blasted and placed out of doors and painted there. Temperature 25 to 27° F. Both coats dried outside.	No appreciable change except a few surface spots, similar to those on Nos. 1 to 5, running across upper right hand side, a few rust spots along lower right hand edge (within 3 in.) and a band of darker color around edges of plate. Extreme edges more like Nos. 1 and 2.	Condition compared favorably with No. 1. About eight scattered rust spots in addition to two of last inspection. (Not considering the surfaces 3 in. from top and bottom edges). Rated 90 per cent.

REPORT OF INSPECTION OF TEST PANELS, OCTOBER, 1920 (*Continued*).

Test No.	Description.	Condition at Altoona, Pa., October 26, 1920.	Condition at Brooklyn, N. Y., October 27, 1920.
7	Sand-blasted and exposed out of doors for seven days during which some rust developed which was not removed before painting. Painted in warm, dry room.	About the same as No. 4, including surface spots.	Surface over center of plate in best condition. A number of ¼-in. rust spots and a good many pin-heads. Rated 80 per cent.
8	Pickled, rinsed in hot water neutralized with alkali solution and again washed. Painted in warm, dry room.	About the same as No. 3, including surface spots.	A considerable number of scattered ¼-in. rust spots developed since last inspection; also some pin-heads. Rated 70 per cent.
9	Pickled as for No. 8 and exposed to weather for seven days. Some rust developed which was not removed before painting. Painted in warm, dry room.	Generally similar to, but of somewhat better appearance than Nos. 4 and 7, and worse than Nos. 5 and 6.	Surface quite generally covered with small rust spots varying from pin-head to ½ in. wide. Spots grouped and becoming continuous along upper left edge and in other places. Rated 40 per cent.
10	As received from mill, were exposed to weather from Aug. 4, 1916 to Jan. 16, 1917, became deeply rusted, especially along diagonal lines. Some mill scale remained between diagonal lines. Surface cleaned with scraper and wire brush. Painted in warm, dry room.	Similar to last inspection with rust blisters more numerous and enlarged.	Condition bad and much worse than on last inspection. Considerable paint still adhering both over mill scale and over rust bands without appreciable difference. Rated 10 per cent.
11	Pickled and cleaned with cold water under pressure. Painted in warm, dry room.	Practically the same as No. 5.	Similar to last inspection without apparent increase in number of rust spots which have become much enlarged. Rated 50 per cent.
16	Incompletely sand-blasted. Painted in warm, dry room.	Surface spots more numerous than on No. 11. One line of rust spots about 5 in. long, 12 in. from bottom and to right of center line. Edges like Nos. 8 and 9.	Spots of last inspection increased in size and about ten new spots, ½ in. in average width. Rated 85 per cent.
	SERIES B.—TESTS ON OLD STEEL		
12	About 25 per cent of surface bare and rusted; old paint on balance. Cleaned with wire brush only, leaving old paint on about 50 per cent of surface. Painted in warm, dry room.	Coating excellent over the rough surfaces. Two ½ in. in diameter dark spots at apices of indentations with rust apparently starting under their centers. Blisters noted in earlier inspections not progressed appreciably.	Several large rust blisters (broken) and many pin-head rust spots, mostly located where the old paint had been removed. Rated 60 per cent.
13	About 25 per cent of surface bare and rusted in spots, old paint on balance. Washed with benzine, scraped leaving old paint on about 50 per cent of surface. Painted in warm, dry room.	Similar to No. 12 only more dark spots, generally at apices of indentations. A rust blister ¾ in. in diameter about 2 in. from center of left side and another near lower left corner.	An area of five spot rusting about 9 in. in diameter at about the center of the plate where mechanical injury had occurred previous to painting. Only a few small (mostly pin-head) rust spots elsewhere on surface. Rated 75 per cent.
14	Approximately 10 per cent of surfaces bare and rusted in spots, old paint on balance. Brush-coated with benzine over and around rust spots and benzine burned off with torch flame. Surface then scraped and wire-brushed. Painted in warm, dry room.	Similar to No. 12. About five dark spots on indentations on right side, one with rust spot ¼ in. in diameter, 8 in. from right side and 8 in. from bottom.	One ½-in. blister in center of plate and one smaller to right of former—otherwise surface practically perfect. Rated 90 per cent.
15	Plates badly indented at several points, apparently by blows of a pick or other similar instrument. Approximately 50 per cent of surfaces bare and rusted. Sand-blasted in warm, dry room and painted therein about three hours later.	Surface mottled with spots of character noted for Nos. 1 to 9 and of about same distribution as on Nos. 3 and 8. Darker color at apices of indentations, with ¼-in. diameter rust spots on several apices.	The break at the apex of indentation near center of plate measured 1 by ¾ in. A number of scattered spots ¼ to ¾ in. diameter. Otherwise good condition. Rated 70 per cent.

REPORT OF SUB-COMMITTEE XV ON SPECIFICATIONS FOR PIGMENTS DRY AND IN OIL WHEN MARKETED IN THAT FORM.

The sub-committee, as originally appointed, consisted of such members of Committee D-1 as were also members of the Government Inter-Departmental Committee for Paint Specification Standardization. The sub-committee was formed to report, in American Society for Testing Materials' form, specifications for pigments dry and in oil when marketed in that form which have been adopted by the Inter-Departmental Committee.

The sub-committee has considered the Inter-Departmental Committee Specifications for Basic Carbonate White Lead, Basic Sulfate White Lead, Red Lead, Zinc Oxide, Leaded Zinc Oxide, Ochre, and Iron Oxide and Iron Hydroxide. Specifications for these various pigments have been drawn up, which, with some slight modifications, are practically the same as the specifications adopted by the Inter-Departmental Committee.

On the question of the substitution of the finer screen for the No. 200 screen, the sub-committee is divided. It was voted, however, in view of the present lack of finer screens, to recommend the insertion of the following footnote in all specifications for pigments in which fineness tests are required:

> "Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness."

The sub-committee also voted to recommend the addition of the following note to all specifications in which fineness tests are required:

> "Specifications for a standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials (1918 Book of A.S.T.M.Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance."

These specifications for basic carbonate white lead, basic sulfate white lead, red lead, zinc oxide, leaded zinc oxide, ochre, and iron oxide and iron hydroxide are attached to this report[1] and are recommended as tentative standards.

Respectfully submitted on behalf of the sub-committee,

H. E. **Smith**,
Chairman.

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[1] See pp. 615-628.—Ed.

REPORT OF COMMITTEE D-2

ON

PETROLEUM PRODUCTS AND LUBRICANTS.

At the meeting of the Executive Committee, held June 23, 1920, the scope of Committee D-2, which, up until then, had been confined to lubricants, was enlarged and the title changed to cover both petroleum products and lubricants. The membership was increased at that time and has been still further increased throughout the year. At the present time the committee has a total membership of 58, consisting of 30 non-producers and 28 producers. The administration of the committee is in the hands of an advisory sub-committee consisting of four elected members and the three officers *ex-officio*. Work of the committee, in the preparation of tests and specifications, is carried on by seventeen sub-committees.

The committee is presenting for adoption as standard a revision of the present standard test for free acid in the Standard Tests for Lubricants (D 47 – 18).[1] The revision does not in any way alter the present standard, but furnishes additional directions when dealing with specific classes of oil by the addition of the following paragraphs:

> "Follow the same method for mineral oils excepting the alcohol which should consist of equal proportions of distilled water and 95-per-cent alcohol.
>
> "In titrating dark-colored mineral oils, the end reaction is better observed when alkali blue 6 B. is used as the indicator."

The committee, with the cooperation of Sub-Committee XI, of Committee D-1, on Paint Thinners Other Than Turpentine, and Sub-Committee XII, of Committee D-1 on Turpentine, has prepared a revision of the present Standard Test for Flash Point of Volatile Paint Thinners (D 56 – 19).[2] This revision is limited to:

1. Broadening the title to include all volatile flammable liquids;
2. Prescribing limits for liquids to be tested;
3. Elaborating the thermometer specifications. The specifications presented cover the thermometers which have been and are now being used with this instrument.

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[1] 1918 Book of A.S.T.M. Standards.

[2] A.S.T.M. Standards Adopted in 1919.

This revision is being presented to the Society by Committee D-1, which originally proposed this test to the Society.

The committee presents for publication as a tentative standard, a revision of the present standard cloud and pour tests of the Standard Tests for Lubricants, (D 47 – 18),[1] and recommends that the present standard cloud and pour tests and cold test be withdrawn from the Standard Tests for Lubricants. An explanation of this recommendation is given in the report of Sub-committee XVI on Cloud and Pour Tests.

The committee is presenting for publication as tentative, a method of test for distillation of gasoline, naphtha, kerosene and similar petroleum products. In the preparation of this test the committee has had the assistance and cooperation of Sub-Committee XI, of Committee D-1, on Paint Thinners Other Than Turpentine, and Sub-Committee XII, of Committee D-1, on Turpentine.

The committee is presenting for publication as tentative, the following additional methods of test:

Method of Test for Melting Point of Paraffin Wax.
Method of Test for Viscosity of Fuel Oils and Other Oils of Similar Viscosity.
Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Petroleum Products.
Method of Test for Sulfur in Naphthas and Illuminating Oils.
Method of Test for Precipitation Number of Lubricating Oils.
Method of Test for Flash and Fire Points by means of Open Cup.
Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester.
Method of Test for Saponification Number.
Method of Test for Water in Petroleum Products.
Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge.
Method of Test for Cloud and Pour Points of Petroleum Products.

Appended hereto are reports of Sub-Committees I, II, III, IV, V, VI, VII, VIII, IX, X, XII, XIII, XIV, and XVI.

This report, and the methods of test recommended for adoption as standards and submission as tentative standards, have been submitted to letter ballot of the committee which consists of 58 members. Fifty-two ballots have been returned and six members have refrained from voting.

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[1] 1918 Book of A.S.T.M. Standards.

	Affirmative.	Negative.	Not Voting.
General Report	44	0	8
Revision of Standard Test for Free Acid	36	3	13
Adoption of Standard Test for Flash Point of Volatile Flammable Liquids	46	0	6
Proposed Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products	43	2	7
Proposed Tentative Method of Test for the Melting Point of Paraffin Wax	33	5	14
Proposed Tentative Method of Test for Viscosity of Fuel Oil	41	3	8
Proposed Tentative Method of Test for Detection of Fee Sulfur and Corrosive Sulfur Compounds in Petroleum Products	38	0	14
Proposed Tentative Method of Test for Sulfur in Napthas and Illuminating Oils	39	1	12
Proposed Tentative Method of Test for Precipitation Number of Lubricating Oils	36	3	13
Proposed Tentative Method of Test for Flash and Fire Points by means of Open Cup	44	0	8
Proposed Tentative Method of Test for Flash Point by Means of the Pensky-Martens Closed Tester	41	2	9
Proposed Tentative Method of Test for Saponification Number	35	4	13
Proposed Tentative Method of Test for Water in Petroleum Products	42	1	9
Proposed Tentative Method of Test for Water and Sediment in Petroleum Products, by Means of Centrifuge	40	2	10
Proposed Tentative Method of Test for Cloud and Pour Points of Petroleum Products	42	2	8

Respectfully submitted on behalf of the committee,

C. P. VanGundy,
Chairman

K. G. Mackenzie,
Secretary.

Editorial Note.

The proposed revisions of the Standard Methods of Test for Lubricants relative to changing the test for free acid and the withdrawal of the Cloud and Pour Test and Cold Test were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The methods as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The twelve proposed tentative methods of test referred to in this report were accepted for publication as tentative and appear on pages 631–678.

REPORT OF SUB-COMMITTEE I ON PETROLATUM.

The sub-committee has been engaged during the last year in investigating the melting points of petrolatums. To obtain information as to methods currently employed by manufacturers and users of petrolatum, samples representing five grades were sent out to the seven members of the sub-committee on melting points. Samples Nos. 1 and 2 were straight petrolatum; Nos. 3, 4 and 5 were blends, the results of several trial mixtures with the definite point of view to make such a range as would compare with grades to be met with commercially. Because of the information gained by this experimental work in connection with routine determinations, it is believed that the melting points at the head of the several columns in the appended table, representing the finished samples, are not far wrong. When the mixture that gave the desired melting point was found, a large sample was made up, thoroughly mixed, rechecked, and the smaller samples withdrawn and forwarded to committee members. Reports have been received from five.

Two members beside the chairman reported melting points by the plate method, which it had hoped would be the one that could be recommended as the referee method because it appears to have so many points in its favor. The method complete is given as the first method in Appendix I.

The routine method in the laboratory of the chairman is as follows:

> The petrolatum is slowly melted and heated to a temperature about 15° F. above its probable melting point. A paper scale thermometer, having a round bulb, is chilled in an ice bath, the bulb wiped dry, thrust into the melted petrolatum, withdrawn immediately and held vertically until the surface dulls. It is then kept at laboratory temperature for one hour. A 500-cc. tall form beaker, about two-thirds filled with water, is placed on a wire support above a gas or electric heater. The coated bulb is held rigidly 1 in. below the surface of the water, the temperature of which is raised at a rate of 5° F. per minute up to 100° F. and then 2° F. per minute to the end of the test. When at least half of the melted petrolatum leaves the bulb the thermometer reading is noted and reported as the melting point.

One member gave a long series of readings taken with an apparatus similar to that described in Lewkowitsch's Chemical Technology, at page 321 in Volume 1 of the fifth edition. In any one test there is not a wider variation than 1°.5 F. but they were all low. This is probably due to the fact that the petrolatum is forced from the platinum wire by the mercury as soon as it is softened sufficiently to become plastic. While accuracy must not be sacrificed for simplicity, this apparatus would seem to be rather too complicated for very extended use.

Another method which likewise measured the softening point of the petrolatum has been suggested by one member. Since it requires so little apparatus, and gives promise of concordant results, this is being detailed as one of the methods for trial during the next year. The description of the limited apparatus required and procedure is given as the second method in Appendix I.

The results of tests by the two methods called attention to the possible error due to differences in specific gravity between the petrolatum and the water and mercury respectively.

Some earlier experiments with the Ubbelohde apparatus in which a blank was run beside a regular melting point, showed plainly a lag in the reading of the petrolatum-covered bulb of about 2° F. Certain rapid changes in the reading of the thermometer following the rising of the melted material from the bulb when using the chairman's method also indicated a lag, probably due to the thermal insulating capacity of the petrolatum.

Two members reported the temperatures at which the first drop left the bulb of the thermometer coated with the melted petrolatum when suspended in test tubes heated in a water bath. The objection here again might be that the insulating power of the coat of petrolatum would not permit the thermometer to record properly.

With these facts in mind, the chairman secured a solid, etched-stem thermometer, which seems to overcome every objection met in the other tests. When used in accordance with the proposed method detailed in Appendix I, quite consistent readings have been obtained. The thermometer is essentially different from all others in that below the mercury bulb is an extension of solid glass of the same diameter as the bulb, 19 mm. long, rounded at the lower end, and having a line etched around it 12.7 mm. from the end. Under the instructions only one coat, and that up to the line, is permitted, thus allowing exposure of the entire bulb to the same temperature as the petrolatum. It is expected that the ring of glass around the stem 50 mm. up from the bottom will prevent rubbing the coating of petrolatum off the glass extension.

Table I of the appendix gives a record of the melting points determined in the cooperative tests.

Indebtedness to the several members of the sub-committee, as well as to the members of the staff of the chairman's laboratory, is hereby gratefully acknowledged.

It is respectfully requested that anyone interested in the work of obtaining the melting points of petrolatum try out as many as possible of the three methods detailed in this report and its appendix, and write the chairman any constructive criticisms. It is hoped and expected that a tentative standard for the purpose will be offered to the Society at its next annual meeting.

Respectfully submitted on behalf of the sub-committee,

FLORUS R. BAXTER,
Chairman.

APPENDIX I.

MELTING POINT OF PETROLATUM.

Saybolt M. P. Apparatus.

Apparatus.—Jacket and stand.

Copper water bath vessel with hangers.

A circular brass plate divided by a scribe into four sections. Within each section there are ten ¼-in. diameter well holes with flat bottoms all of equal depth as per the thickness of the brass plate. In the center of the plate there is a ⅜-in. iron pipe threaded hole. A number of round pine match-sticks with smooth ends smoothed and varnished to 40 Stubbs gage and 1¼ in. long.

A regular wax melting point thermometer with ¼° F. scale.

Procedure.—Clean the well holes thoroughly, wash with naphtha and dry.

With the plate lying flat and level and in about 60 to 70° F. temperature atmosphere, fill the well holes over-full with melted petrolatum.

After the petrolatum in the well holes has solidified, cut off the excess down to and level with surface of the plate, by the use of a thin square-end spatula blade.

Stand upright in the center of each well-hole, one of the sticks carefully pushed down straight through the solid petrolatum until the end of the stick "touches bottom."

Having the bath prepared with water of 60 to 70° F. temperature, and filled so that the water level is 1¾ in. above the upper surface of plate, carefully, without disturbing the sticks, adjust the plate and its load in the hangers.

Suspend the thermometer by ring stand or other device so that its bulb is half through the center hole of the circular plate.

Heat with small Bunsen burner flame so that to 90° F. the temperature shall not rise faster than 2° F. per minute, and from 90° F. up, not faster than 1° F. per minute (even slower nearing the critical point conduces to better uniformity of results).

The critical point is reached when the sticks leave their anchorage and float to the surface of the water.

The plate has been designed to make tests of four samples at the same time, each quarter section being allotted for ten trials of one sample.

The average temperature (in whole degrees) within which the third, fourth, fifth, sixth, seventh and eighth sticks rise to the surface shall be taken as the critical point and may be termed the melting point. If care is taken in the several important details of the test, the six sticks will rise practically together, or within ¼° F.

Between each use of the plate the well holes must be thoroughly cleaned, rinsed with naphtha and dried.

A short piece of threaded ⅜-in. pipe may be used in the center hole to lift the plate out and into bath, removing the pipe when making the test.

The sticks must not be left floating and soaking in the water after a test is finished, but should be removed immediately and dried.

A piece of zinc may be added, resting about 1 in. off the bottom of bath with the end in view of spreading the heat currents.

SECOND METHOD FOR OBTAINING MELTING POINT OF PETROLATUM.

Apparatus.—Glass tube 3½ in. long containing a constriction 1 in. from the lower end with a mark etched on the tube ½ in. from the lower end.

Water bath, with means of agitation and heating.

Procedure.—The sample is first melted and carefully freed from any air bubbles. When the sample has cooled, the melting-point tube is filled from the bottom end up to the constriction with a plug of petrolatum. This may be readily accomplished by pressing the tube into the petrolatum, and at the same time applying suction at the upper end. The tube is then wiped clean on the outside and placed for one hour in a water bath maintained at 77° F. Care must be taken to see that no water is allowed to enter the melting point tube above the petrolatum. At the expiration of one hour the tube is immersed in the water bath to a mark etched close to the upper end. The water bath at this point should be at a temperature of 77° F. Heat is then applied and maintained at such a rate that the temperature of the bath rises 5° F. per minute.

TABLE I.—RESULTS OF COOPERATIVE TESTS ON MELTING POINTS OF PETROLATUM.

Method.	Melting Points, deg. F.					Remarks.
	1	2	3	4	5	
V. O. Co. Water Method	132.0	123.0	119.5	117.0	109.0	
No. 1 Laboratory Plate Method	134.5	124.4	124.9	121.0	113.5	5° F. per min.
No. 2 Laboratory Plate Method	126.5	119.1	117.8	117.8	114.8	2° to 90° F., then 1°.
No. 3 Laboratory Plate Method	130.6	122.0	122.4	117.7	107.6	2° to 90° F., then 1°.
BULB COATED						
No. 1 Laboratory Water Method	137.0	127.0	129.0	125.0	118.0	3 coats, 10° F. 1 in. depth.
No. 3 Laboratory Water Method	130.7	123.3	119.7	117.7	110.8	1 coat, 5° F.
No. 5 Laboratory Platinum-Mercury Method	124.8	118.3	114.8	112.3	99.6	7 tests, 1°.8 to 2°.7. Variation 1°.5.
No. 4 Laboratory Drop-in-air Method	132.6	121.1	119.3	115.3	100.0	10 tests, 18°. Variation 8°.1.
No. 3 Laboratory Drop-in-air Method	128.0	121.0	122.0	116.3	110.3	1 coat. 5°. Variation 2°.0.
BULB ¾ COATED.						
No. 3 Laboratory Water Method	128.8	121.8	120.0	117.5	110.0	2 coats, 5°. Variation 3°.0.
No. 2 Laboratory Drop-in-air Method	132.6	127.3	127.8	123.3	118.0	¾ bulb 5° to 100°, then 2°. Variation 2°.5 F.
No. 6 Laboratory Drop-in-air Method	133.0	122.0	125.0	120.0	115.0	¾ bulb 5° to 100°, then 2°.
No. 3 Laboratory Drop-in-air Method	134.5	123.0	122.8	120.5	111.1	¾ bulb 5° to 100°, then 2°.
No. 3 Laboratory Water Method	131.0	.....	121.0	.....	109.7	Special thermometer. 2 tests. Variation 2°.3 F.
No. 3 Laboratory Drop-in-air Method	131.2	.....	119.0	...	110.0 108.0 109.6	Special thermometer. 2 tests. 1st drop. 2d drop.

At the point when the petrolatum becomes soft enough to be forced upward by the hydrostatic pressure until its lower edge is level with the mark etched ½ in. from the bottom of the tube, the temperature is read and called the melting point of the sample.

OBTAINING MELTING POINT OF PETROLATUM BY MEANS OF SOLID ETCHED-STEM THERMOMETER WITH GLASS EXTENSION.

Definition.—For the purpose of this method the melting point is understood to be the temperature reading at which the product becomes fluid enough to leave the thermometer used in making the determination.

Apparatus.—Special Thermometer.

Test Tubes, 1 in. by 6 in.

Beakers, tall form 600-cc.

Procedure.—Obtain sample that exactly represents batch under inspection. Melt slowly and heat to a temperature 15° F. above its probable melting point. Chill thermometer bulb to 40° F., wipe dry, thrust into melted petrolatum, remove immediately, hold vertically until surface dulls, and suspend at room temperature for 60 minutes.

Suspend thermometer in the test tube with lowest end of bulb 15 mm. from the bottom. While glass ring above bulb is expected to prevent rubbing of coating of petrolatum, care should be exercised in inserting thermometer into test tube.

Surround this assembly with water bath at 60° F. Raise temperature of bath 2° F. per minute to 100° F., then 1° F. to end of test. Read thermometer when first drop leaves it and record. An average of three such tests, if the variation does not exceed 2° F., may be given as the melting point of the sample under test. If a greater variation, take the average of five determinations.

REPORT OF SUB-COMMITTEE II ON GAS ABSORBENT OIL.

Since its organization, the sub-committee has held two meetings. After examining a number of existing specifications for gas-absorbent oils the sub-committee deemed it necessary to give careful study to the service requirements of absorbent oils before undertaking to write specifications and to this end has undertaken cooperative testing work to throw further light on the following questions:

1. How to rate the absorption power of oil.
2. Determine the relative tendency of oils to form emulsions during service, and the cause thereof.
3. Determine the effect of unsaturated hydrocarbons.
4. Determine the viscosity and pour test required for ease in handling at all working temperatures.
5. Determine distillation test requirements.

It is the sense of the sub-committee that the fundamental knowledge of the service requirements of gas-absorbent oils is so limited at this time that a large amount of testing work and some research will be necessary to clear up disputed points. All members of the sub-committee are entering actively into this work.

Respectfully submitted on behalf of the sub-committee,

CHARLES A. LUNN,
Chairman.

REPORT OF SUB-COMMITTEE III ON PARAFFIN WAX.

The sub-committee presents for adoption as a tentative standard, a method of test for the melting point of paraffin wax.[1]

Respectfully submitted on behalf of the sub-committee,

C. K. FRANCIS,
Chairman.

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[1] See p. 638.—ED.

REPORT OF SUB-COMMITTEE IV ON GREASE.

Under date of February 17, the chairman transmitted to the members of the sub-committee the results of some work done on a method for the determination of grease consistencies. The members of the sub-committee were requested to give their opinions of this work and in addition to answer several questions concerning the most important points to be covered in the analysis of grease—also to give suggestions in methods.

The opinion seems to be generally held that methods for consistency and melting point should be standardized. From the suggestions put forward and from promises of future suggestions, there will be considerable divergence of opinion as to the proper methods and type of apparatus to use in the determining of these two properties. Since the majority of greases have no true melting point, we will apparently be compelled to fix upon some method of determining a definite softening point. There are several promising methods which will be worked upon later.

The wide range in consistency exhibited by different grades of grease, and the fact that any disturbance, even casual handling, tends to change this property, render its determination a problem somewhat difficult of both convenient and exact standardizing. Several methods have been tried and proposed and it is hoped that something worth while may be evolved.

The members of the sub-committee heard from are also in very good accord on the necessity of standard analytical procedure for the determination of soaps, free alkali, fat, acid, and water in greases. As a result of considerable laboratory experience and some suggestions which have been received, there has been prepared a tentative scheme for grease analysis which covers in the main the analytical points logically to be determined. This draft will be transmitted to the sub-committee members in the very near future. At the same time, samples of grease will be sent, upon which tests will be made and results compared. From these results, and from suggestions which should be received it is hoped that we shall be able to prepare a satisfactory analytical scheme.

Respectfully submitted on behalf of the sub-committee,

G. Cash,
Chairman.

REPORT OF SUB-COMMITTEE V ON VISCOSITY.

The sub-committee has prepared a tentative test for viscosity of fuel oils, and other oils of similar viscosity, by means of the Saybolt Furol Viscosimeter.[1]

The following table shows the approximate relation between time Saybolt Universal and time Saybolt Furol, and is given merely as a guide in determining which instrument to use, in accordance with the instructions of Section 4 of the Saybolt Furol test. It should not be used for viscosimeter conversions.

Time, Furol, sec.	Time, Ratio.	Time, Furol, sec.	Time, Ratio.
25	8.8	50	9.5
30	9.1	75	9.7
35	9.2	100	9.8
40	9.4	150 and over	9.9

The sub-committee is agreed that it is desirable to further standardize the Saybolt Universal Viscosimeter so as to make the agreement between different laboratories as close as possible. With this end in view it has adopted an equation of the form

$$\frac{\text{absolute viscosity}}{\text{density}} = A\,t - \frac{B}{t}$$

where t is the Saybolt viscosity, and A and B are instrumental constants with suitable tolerances. It believes that B is sufficiently fixed, by the standard dimensions already adopted, as 1.79 to 1.82.

A special section has been appointed to confer with Mr. George M. Saybolt on matters of construction and on further methods of standardization which would be acceptable to him and to the United States Bureau of Standards.

Respectfully submitted on behalf of the sub-committee,

WINSLOW H. HERSCHEL,
Chairman.

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[1] See p. 642.—ED.

REPORT OF SUB-COMMITTEE VI ON COLOR.

The work of this sub-committee has been conducted entirely in the laboratories of The Atlantic Refining Co. Suggestions made from time to time and brought to the attention of the chairman have been thoroughly investigated. It is believed that the instrument for color determination as developed and now undergoing trial can be offered to Committee D-2 in the near future.

Instrument.—The instrument is of the same general type as the Saybolt Refined Oil Colorimeter, consisting of an eye-piece where two triangular optical fields represent a color standard and the oil under examination, respectively. The oil under examination is varied in depth by means of an immersion tube similar to that used on the Duboscq. A rack and pinion attachment is used to raise and lower the immersion tube, and the depth of oil necessary to match the color standard is read on a scale on the face of the instrument. This scale is made up on a reciprocal base so that it reads directly in color units per unit volume of oil. The advantage from a manufacturer's point of view in using this scale is the fact that mixes of oil of different colors may be made and color obtained as calculated in a simple mathematical manner. Light is reflected through the oil and color tubes by means of an opal glass reflector set at an angle of 45 deg. Considerable work on the optical arrangement of the instrument has been carried on, introducing diaphragms, etc., so as to restrict the field presented to view in such a manner as to lessen the chance for error. Optically, the instrument as assembled today is as nearly perfect as possible with the present knowledge of the subject.

Source of Light.—Considerable experimental work has shown that light is a very important factor in color measurement. The quality and intensity of light will give different results on different types of oils. Even the character of current, whether A. C. or D. C., can readily be detected by the experienced operator. The system being tried consists of a specially designed box containing a 100-watt stereopticon lamp (concentrated filament) so placed as to throw diffused rays of light within the box. An aperture is provided with a blue glass screen through which the rays from the lamp are filtered, passing directly to the opal glass reflector of the instrument. The rays approach the so-called daylight rays and by the arrangement are diffused and steady. Readings obtained are precise and uniform.

Color Standards.—Two color standards have been constructed from Pyralin, (1) Pale, and (2) Red, representing as far as possible the true colors as contained in the oils. These are mounted between optical plano glass disks by means of a special cement. Considerable study as to the technique of mounting the standard has been made, and standards are at present undergoing trial in various laboratories of The Atlantic Refining Co. as to permanency and usefulness. Reports received to date on these standards are favorable.

Respectfully submitted on behalf of the sub-committee,

T. G. DELBRIDGE,
Chairman.

REPORT OF SUB-COMMITTEE VII ON SULFUR DETERMINATION AND DIFFERENTIATION.

The sub-committee has prepared a tentative method for detection of sulfur and corrosive sulfur compounds; and a tentative method for the determination of sulfur in naphthas and illuminating oils.[1]

The sub-committee is also presenting for information and criticism the following method for the determination of total sulfur in petroleum products.

METHOD FOR DETERMINATION OF TOTAL SULFUR IN PETROLEUM PRODUCTS.

Scope.—This method for determination of sulfur is applicable to all petroleum products but is especially recommended for products other than naphthas and illuminating oils.

Apparatus.—Accurate results cannot be expected unless a suitable bomb is used. There are several of these on the market at the present time. Among the characteristics which are considered essential are the following: The capacity should be not less than 300 cc. and preferably about 375 cc. The lining should be chemically and physically resistant. When closed and filled under pressure, the bomb should show no leak. The oxygen charging valve is often faulty in this respect. The design and construction of the bomb should be such as will prevent exposure of the gasket to gases within the bomb.

Procedure.—Place 20 cc. of distilled water in the bottom of the bomb. Use 0.5 to 1.0 g. of oil, weighed into the sample cup of the bomb, when the material is not volatile. For volatile materials use either a small gelatine capsule or a very small glass bulb of the type used in the ultimate organic analysis of such liquids. If the latter is used, place a few drops of sulfur-free alcohol in the sample cup to start combustion. Arrange the ignition mechanism according to the bomb used and close the bomb tightly. Admit oxygen until a pressure of 35 to 40 atmospheres is reached. The higher pressure is preferable. Ignite. Place the bomb in cold water for 20 minutes. Shake vigorously for 25 seconds and allow to drain for five minutes. Release the pressure rather slowly and open the bomb. Using distilled water in a wash bottle with a very fine jet, wash the wires and cover thoroughly, allowing the washings to collect in the bomb. In the same way wash the sample cup held by small tongs. Transfer the solution from the bomb to a 500-cc. beaker and wash the inside of the bomb thoroughly. The total volume of solution thus obtained need not exceed 350 cc. Avoid any loss of material by spattering or otherwise in the various washings.

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[1] See pp. 643 and 644.—ED.

Filter the solution through a washed filter paper into another beaker, of smaller size if possible. Wash the filter thoroughly. Add 2 cc. of HCl (sp. gr. 1.20) and 10 cc. of saturated bromine water. Evaporate to about 75 cc. over a hot plate or steam bath. To the hot solution add 10 cc. of a 10-per-cent barium chloride solution, as hot as possible, in a very fine stream or dropwise so that 30 to 45 seconds are required. Stir vigorously with a glass rod during this addition and for four minutes afterward. Allow the precipitate to settle for one hour on a steam bath. Cool and let stand for at least one hour at room temperature. Filter carefully through a suitable ashless filter paper and wash the precipitate with hot water, first by decantation and then on the filter till free from chloride. Transfer the wet filter paper and precipitate to a weighed platinum crucible. Dry carefully over a low flame. Allow the filter paper to burn away and then ignite until the precipitate is just burned white. Cool in a desiccator and weigh. From the increase in weight which is barium sulfate, calculate the percentage of sulfur as follows:

$$\text{Percentage of Sulfur} = \frac{\text{grams of } BaSO_4 \times 13.734}{\text{grams of oil used}}$$

Respectfully submitted on behalf of the sub-committee,

FLORUS R. BAXTER,
Chairman.

REPORT OF SUB-COMMITTEE VIII ON DISTILLATION.

The sub-committee, with the cooperation of Sub-committees XI and XII of Committee D-1, has prepared a tentative method of distillation for the examination of gasoline, naphtha, kerosene and similar petroleum products.[1]

Respectfully submitted on behalf of the sub-committee,

C. K. FRANCIS,
Chairman.

REPORT OF SUB-COMMITTEE IX ON PRECIPITATION.

Sub-committee IX on Precipitation has during the past year made a careful study of a gravimetric method and has reached the unanimous conclusion that such a method should not be recommended: first, because the results obtained are not concordant and second, because it requires too much time, apparatus and skill. For this reason the sub-committee has prepared a volumetric method by centrifuge, which it presents for adoption under the title, "Tentative Method of Test for Precipitation Number of Lubricating Oils."[2]

Respectfully submitted on behalf of the sub-committee,

T. G. DELBRIDGE,
Chairman.

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[1] See p. 631.—ED.

[2] See p. 648.—ED.

REPORT OF SUB-COMMITTEE X ON OXIDATION AT HIGH TEMPERATURES.

The members of the sub-committee have confined their attention largely to the design of an oven which shall be suitable for the test in question, and which shall be made at a reasonable cost. The details of the test method, such as the size and material of the containers for the oil samples, and the method of introducing the samples into the containers have also been considered. At least four different ovens which give good results in the laboratories which developed them, are available for selection. The sub-committee hopes that the best features of each will lead to the production of a design which can be agreed upon for presentation to the Society.

Respectfully submitted on behalf of the sub-committee,

W. F. FARAGHER, *Chairman.*

REPORT OF SUB-COMMITTEE XII ON FLASH.

Sub-committee XII submits the following outline of results for the work of the present year:

1. A revision of the Standard Method for Determining the Flash Point of Volatile Paint Thinners (Serial Designation: D 56 - 19). The revision involves changing the title to "Standard Method of Test for Flash Point of Volatile Flammable Liquids," broadening the statement of scope and adding specifications for the thermometer. The specifications are written to cover the thermometers that have been actually sold and used. It involves, therefore, no change in apparatus or method, but simply more completeness in the description of the former. This revision was prepared with the cooperation of Sub-Committee XI and Sub-Committee XII of Committee D-1 and is being presented by Committee D-1 as a revision of the present standard. The revision will be found in the report of Committee D-1.

2. A tentative method for determining open cup flash and fire points. The method involves the use of the Cleveland open cup with a standardized set of accessories and a definite operating procedure.[1]

3. A tentative method for determining flash point by means of the Pensky-Martens closed tester.[2] Specifications for apparatus have been prepared which seem to cover a large proportion of the imported instruments already in service and which will be used as a guide in the manufacture of American Pensky-Martens testers. A definite operating procedure is outlined.

Respectfully submitted on behalf of the sub-committee,

ERNEST W. DEAN, *Chairman.*

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[1] See p. 651.—ED.

[2] See p. 655.—ED.

REPORT OF SUB-COMMITTEE XIII ON SAPONIFICATION.

The sub-committee has felt that its most important problem was to establish, first of all, a standard and reliable method for the determination of Saponification Number. To that end the members of the sub-committee were asked to submit their own methods which were found in many points to agree, and from these methods a method was evolved. This method formed a working basis for cooperative work, and to determine its reliability samples were submitted to the members of the sub-committee and determinations were made.

Six of the eight laboratories receiving samples have submitted reports and the results of their work are shown in Appendix I. In all cases these laboratories were requested to use their own method, in case they had one different from the tentative method, for comparative purposes. This was done in all but two cases as will be noted.

In connection with the laboratory methods used the variations in each laboratory method from the proposed tentative method are noted:

Laboratory No. 1 used alcoholic soda and purified denatured alcohol.

Laboratory No. 2, in the so-called Special Method, simply gave the results of six tests, giving a direct titration whereas the tentative method as submitted called for a back titration. The results indicate that the back titration is apt to give higher results than theory warrants.

Laboratory No. 4 used a N/3 alcoholic potash solution and used N/3 acid for titrating. This laboratory also used ether and petroleum naphtha in cases of heavy admixtures of petroleum oils.

Laboratory No. 5 used as its method one requiring a special acid solution giving results in percentages of oleic acid from which various factors are used for individual oils. The results in this case were received as percentages of fat and the figures in Table I of the appendix represent the percentages multiplied by 195, a hypothetical factor. The method itself is given as the Baxter Method in the appendix.

Laboratory No. 6 used a method not greatly different from the Sub-committee Method, and not as carefully described, and reported results as Saponification Number.

The results of the comparative work show an average very close to the theoretical average obtained from the actual weights of the fats and petroleum oils used in preparing the test mixtures.

In two cases, where laboratories Nos. 4 and 6 ran high, as compared to the theoretical figures, it will be noted that they also ran exceedingly high in the Saponification of the fat submitted, which suggests that a similar error existed in their work all the way through, either as a result of the method of titrating or some error developed in determining the strength of the blank. With the exception of these two laboratories the Saponification Numbers of the pure fat ran very close to the theoretical 195. Following this comparative work the method was carefully revised, and is presented as a Tentative Method of Test for Saponification Number.[1] It is considered advisable to report the results in terms of Saponification Numbers, and then apply factors for the various oils dependent upon what material has been used for compounding.

The sub-committee plans further work during the coming year in investigating the application of this test to other petroleum products.

Respectfully submitted on behalf of the sub-committee,

D. K. FRENCH,
Chairman.

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[1] See p. 663.—ED.

APPENDIX I.

RESULTS OF COOPERATIVE WORK FOR SAPONIFICATION NUMBER ON MIXTURES OF OILS SUBMITTED TO COMMITTEE MEMBERS.

Oil used: Acidless Tallow.

TABLE I.—SAPONIFICATION NUMBERS.

	SAMPLE NO.					
	1	2	3	4	5	6
Laboratory No. 1						
Sub-Committee Method	30.4	20.1	10.9	193.8	0.5	0.8
Laboratory Method	26.5	20.5	9.4	197.9	0.7	0.9
Laboratory No. 2						
Sub-Committee Method	32.3	20.3	10.9	197.7	0.29	0.41
Special Method	32.0	....	....	....	....	....
Laboratory No. 3						
Sub-Committee Method	30.26	19.51	10.11	194.96	0.55	0.47
Laboratory Method	....	....	....	....	....	....
Laboratory No. 4						
Sub-Committee Method	33.58	20.73	11.76	202.8	0.39	0.42
Laboratory Method	31.12	19.95	11.94	194.8	....	....
Laboratory No. 5						
Sub-Committee Method	31.59	19.5	9.75	195.0	0.0	0.0
Laboratory Method	32.0	19.3	10.33	195.2	....	....
Laboratory No. 6						
Sub-Committee Method	32.26	22.02	10.52	203.4	0.54	1.11
Laboratory Method	29.50	18.94	9.82	194.3	0.83	1.22
Theory	31.84	19.82	10.49	....	0.0	0.0
Average (Sub-Committee Method)	31.73	20.36	10.66	197.8	0.45	0.64

BAXTER METHOD.

SOLUTIONS REQUIRED.

Approximately N/2 alcoholic potassium hydroxide.—Dissolve 33 g. of KOH in about 25 cc. of water, pour 1000 cc. purified ethyl alcohol while stirring. Settle two hours and filter. (Note 1)

Clean neutral gasoline. (Note 2)

Standard 5N/28 hydrochloric acid. (Note 3)

Phenolpthalein indicator. Dissolve 0.1 g. phenolpthalein in 100 cc. 50-percent ethyl alcohol. (Note 4)

SAPONIFICATION.

Weigh 5 g. of the oils into a 200-cc. Erlenmeyer flask. Add twice the amount of alcoholic KOH solution estimated to be required to saponify the fat. With very small percentages and with difficultly saponifiable fats add 10 cc. gasoline. (For sperm oil or wool grease, saponification should be run in a pressure flask over boiling water.) Connect the Erlenmeyer flask with an aerial condenser. Place oil on steam bath or hot plate for 90 minutes, shaking occasionally. Remove, add about 75 cc. water (Note 5) and titrate with the standard 5N/28 HCl using about 0.5 cc. P. T. solution for indicator. Run duplicates and one or two blanks. The number of cubic centimeters of alcoholic KOH required to saponify, calculated to 5N/28, is the percentage of fatty acid in the sample as oleic. The percentage of fat can be obtained by multiplying this figure by the following factors depending upon the nature of the fat (Note 6): Olive, cotton, linseed, whale, menhaden, lard, tallow, neatsfoot, 1.054; colza, etc., 1.161; blown oils, Japan wax, 0.925; sperm, 1.538; cocoanut, 0.78; wool grease, 2.0.

NOTES.

1. Sodium hydroxide is a great nuisance as a saponifier. It works slower. If further work is to be done on the fatty acids, a soda soap is more difficult to handle, as it is harder and less soluble than a potash one.

2. Ordinary motor spirit or VM and P naphtha is as efficient as benzene, is always available and requires no preparation.

3. By the use of the special hydrochloric acid, calculation is minimized. Titrating 5 g. fat with KOH solution standardized against this gives free fatty acids direct.

4. Using a 0.1-per-cent solution of P.T. less care is necessary in adding it. Fifty-per-cent alcohol is amply strong.

5. The addition of water here causes a milky emulsion to be formed if mineral oil be present. The end point can be read much more easily than when the solution is clearer.

6. This does not take the free fatty acids into consideration. For ordinary fats the error is small; but when the free fatty acids are high the error is a factor. We always subtract the free fatty acids percentage before multiplying by the factor and adding it to the product.

REPORT OF SUB-COMMITTEE XIV ON WATER AND SEDIMENT.

The sub-committee has prepared a method for the accurate determination of water in petroleum products by distillation,[1] with the recommendation that it be presented to the Society as a tentative method for determination of water in petroleum products.

It is the common practice at the present time to determine what is called water and sediment, particularly in fuel oils, by dilution of the oil with a suitable solvent and centrifuging the resulting mixture. The sub-committee has carefully investigated this subject and is of the opinion that there is no reliable method available at the present time for this determination. It feels, however, that because of the general use of such a method, a standardized method of procedure is desirable. The sub-committee has, accordingly, prepared a method for determination, by centrifuge, of water and sediment, with the recommendation that it be presented to the Society for adoption as a tentative standard.[2]

Respectfully submitted on behalf of the sub-committee,

T. G. Delbridge,
Chairman.

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[1] See p. 666.—Ed.

[2] See p. 670.—Ed.

REPORT OF SUB-COMMITTEE XVI ON CLOUD AND POUR TEST.

Committee D-2, in its report to the Society in 1917,[1] presented tentative methods for Cloud and Pour Test and for Cold Test. At that time the committee stated:

> "No one method appears to give for all oils the information sought by this test, and it is believed desirable to make a division into groups of oils to be tested."

Accordingly the Cold Test was applied to steam cylinder and black oils, and the Cloud and Pour Test to all other lubricating oils.

Not only was this method of procedure cumbersome, but the increased use of higher viscosity lubricants resulted in uncertainty in the matter of classification and of the test to be applied. The sub-committee was accordingly created for the purpose of not only revising, in general, the Cloud and Pour Test and the Cold Test, but also, if possible, to prepare one test which would be satisfactory for both classes of oil.

The sub-committee has made such revisions in the Cloud and Pour Test as to make it applicable to all classes of oil. Therefore, it recommends that the method prepared[2] be presented to the Society as a tentative method of test for cloud and pour points of petroleum products. It further recommends that the present standard of the Society for Cloud and Pour Test and Cold Test, Standard Tests for Lubricants (D 47 - 18),[3] be withdrawn.

Respectfully submitted on behalf of the sub-committee,

T. G. Delbridge,
Chairman.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XVII, Part II, p. 464 (1917).

[2] See p. 674.—Ed.

[3] 1918 Book of A.S.T.M. Standards.

REPORT OF COMMITTEE D-4
ON
ROAD AND PAVING MATERIALS.

During the past year Committee D-4 has been actively engaged in the preparation of additional specifications for road materials in order to cover in so far as possible all classes of material now in common use. It has been somewhat handicapped in this work owing to the fact that certain tests which it was desired to include in the specifications have not as yet been offered to the Society. Descriptions of certain of these tests are presented this year as tentative standards, but in the case of viscosity limitations it has been found necessary to refer to a test which is at present in common use but which the committee is not prepared to recommend as a tentative standard, owing to the fact that it is expected that next year sufficient data will be at hand to substitute a different apparatus, which is at present under investigation by a number of the committees. It is believed, however, that this matter should not delay the presentation to the Society of the specifications with viscosity requirements owing to the demand for such specifications by engineers and public service bodies throughout the country.

1. *Standard Test for Penetration of Bituminous Materials* (*D 5 - 16*).[1]—This method was adopted in 1916 but was subject to criticism owing to the rather indefinite description of the needle in Section 3. In Appendix I to the 1920 Report of Committee D-4 a proposed new needle was described, but at that time the committee was not ready to make definite recommendations for revision. This year, as a result of further work, it is prepared to offer such revision, which involves a change of wording in Section 3. Committee D-4 therefore recommends that Standard Test for Penetration (D 5 - 16) be amended by changing Section 3 from its present form: namely,

> "The needle for this test shall be a cylindrical steel rod 50.8 mm. (2 in.) long and having a diameter of 1.016 mm. (0.04 in.) and turned on one end to a sharp point having a taper of 6.35 mm. (¼ in.)."

to read as follows:

> "The needle for this test shall be a cylindrical steel rod 50.8 mm. (2 in.) long, having a diameter of 1.01 to 1.02 mm. and having a taper of 6.34 to

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[1] 1918 Book of A.S.T.M. Standards.

6.36 mm. measured on its axis. After tapering, the point shall be "blunted" by grinding off to a truncated cone, the smaller base of which shall be from 0.14 to 0.16 mm. in diameter."

The committee recommends that this amendment be adopted by the Society this year as standard, in view of the fact that the modification of the needle was described in the 1920 report and has been found satisfactory.

2. *Standard Method for Determination of Softening Point of Bituminous Materials Other than Tar Products (D 36 - 19).*[1]—Since the adoption of this standard, attention has been called to an error in the description of the glass vessel and the impossibility of determining the softening point of materials above 80° C. with the thermometer which has been described. To correct these errors, Committee D-4 recommends that the standard method be amended as follows:

1. *Section 2 (c).*—Change from its present form, namely:

"A glass vessel, capable of being heated, not less than 11 cm. (4.33 in.) in diameter by 14 cm. (5.51 in.) deep. (A 600-cc. beaker, Griffin low form, meets this requirement.)"

to read as follows:

"A glass vessel capable of being heated, not less than 8.5 cm. (3.34 in.) in diameter and measuring 10.5 cm. (4.13 in.) in depth from the bottom of the flare (a 600 cc. beaker, low form, meets this requirement)."

2. *Sub-heading (A) under "Testing."*—Change to read as follows by the addition of the italicized figures and the omission of the figures in brackets:

"(*A*) Bituminous materials having softening points [90° C. (194° F.)] *80° C. (176° F.)* or below."

3. *Sub-heading (B) under "Testing".*—Change to read as follows by the addition of the italicized figures and the omission of the figures in brackets:

"(*B*) Bituminous materials having softening points above [90° C. (194° F.)] *80° C. (176° F.)*"

4. *Section 8.*—Change from its present form, namely:

"Use the same method as given under (A). except that glycerin shall be used instead of water."

to read as follows:

"Use the same method as given under (*A*) except that glycerin shall be used instead of water and that the thermometer shall conform to the following specifications:

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[1] A.S.T.M. Standards Adopted in 1919.

Total length	370–400 mm. (14.57 – 15.75 in.)
Diameter of stem	6.5–7.5 mm. (0.256 – 0.295 in.)
Bulb length, not over	14 mm. (0.55 in.)
Bulb diameter	4.5 – 5.5 mm. (0.177 – 0.217 in.)

The graduations shall be from 30 to 160° C. in 0°.5 C. and shall be clear cut and distinct. The 30° mark shall be at least 75 mm. above the bottom of the bulb. The length between the 30° mark and the 160° mark shall be between 230 and 275 mm.

The thermometer shall be furnished with an expansion chamber at the top and have a ring for attaching tags. It shall be made of a suitable quality of glass and so annealed as not to change its readings under conditions of use. It shall be correct to 0°.25 C. as determined by comparison at full immersion with a similar thermometer calibrated at full immersion by the Bureau of Standards."

In view of the fact that it is considered inadvisable to allow the standard to be reprinted in its present form, Committee D-4 recommends that the Society adopt as standard the revision as described.

3. *Tentative Tests Recommended for Adoption as Standard.*—No criticisms of the following tentative tests have been received and as the committee has found no reason to make any changes, they are recommended to the Society for adoption as standard:

Tentative Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 – 20 T).[1]

Tentative Test for Quantity of Clay and Silt in Sand for Highway Construction (D 74 – 20 T).[2]

4. The Committee recommends that the following tentative specifications, tests and methods be continued for another year as tentative:

Tentative Specifications for Block for Granite Block Pavements (D 59 – 19 T).

Tentative Specifications for Workability of Concrete for Concrete Pavements (D 62 – 20 T).

Tentative Specifications for Commercial Sizes of Broken Stone and Broken Slag for Highway Construction (D 63 – 20 T).

Tentative Specifications for Commercial Sizes of Sand and Gravel for Highway Construction (D 64 – 20 T).

Tentative Specifications for Broken Slag for Waterbound Base (D 65 – 20 T), with the title amended by the addition of "and Wearing Course."

Tentative Specifications for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 – 20 T).

Tentative Specifications for Natural or Artificial Sand-Clay Mixtures for Highway Surfacing (D 67 – 20 T).

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 770 (1920).

[2] *Ibid.*, p. 774.

Tentative Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (D 70 - 20 T).

Tentative Test for Specific Gravity of Asphalts and Tar Pitches Sufficiently Solid to be Handled in Fragments (D 71 - 20 T).

Tentative Test for Quantity of Clay in Sand-Clay, Topsoil, and Semi-Gravel for Highway Construction (D 73 - 20 T).

Tentative Methods for Sampling of Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, including Some Material Survey Methods (D 75 - 20 T).

5. *Proposed Tentative Method of Test for Ductility of Bituminous Materials.*—It is recommended that the Proposed Tentative Method of Test for Ductility of Bituminous Materials appended hereto[1] be published as tentative.

6. *Proposed Tentative Method of Test for Water in Bituminous Materials.*—It is recommended that the Proposed Tentative Method for Determination of Water in Bituminous Materials appended hereto[2] be published as tentative.

Committee D-4 also recommends that this test be considered by a conference committee composed of members of Committees D-4 and D-2.

7. *Proposed Tentative Specifications.*—Committee D-4 recommends that the following proposed tentative specifications appended hereto[3] be published as tentative:

(*a*) Specifications for Calcium Chloride for Dust Prevention;

(*b*) Specifications for Asphalt Cement, 40 to 50 Penetration.

(*c*) Specifications for Asphalt Cement, 50 to 60 Penetration.

(*d*) Specifications for Asphalt Cement, 60 to 70 Penetration.

(*e*) Specifications for Asphalt Cement, 70 to 90 Penetration.

(*f*) Specifications for Asphalt Cement, 90 to 120 Penetration.

(*g*) Specifications for High-Carbon Tar for Surface Treatment, Cold Application.

(*h*) Specifications for Low-Carbon Tar for Surface Treatment, Cold Application.

(*i*) Specifications for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).

(*j*) Specifications for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product).

(*k*) Specifications for High-Carbon Tar for Surface Treatment, Hot Application.

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[1] See p. 704.—ED.

[2] See p. 706.—ED.

[3] See pp. 679–703.—ED.

(*l*) Specifications for Low-Carbon Tar for Surface Treatment, Hot Application.

(*m*) Specifications for High-Carbon Tar Cement.

(*n*) Specifications for Low-Carbon Tar Cement.

(*o*) Specifications for Coal-Tar Pitch for Block Filler.

In addition, the committee wishes to state that it has kept in touch with the work of committee D-2 relative to the open cup flash point test which that committee will recommend to be published as tentative and that it approves of such recommendation. It suggests, however, that the question of thermometer specifications be referred to Committee E-1 and that Committee D-2 should look into the matter of designing a proper handle for the cup.

The results of a letter ballot of the committee upon the recommendations which have been made relative to the adoption of tentative standards and the submission of new standards is as follows:

Items.	Affirmative.	Negative.	Not Voting.
I. TENTATIVE STANDARDS RECOMMENDED FOR ADOPTION.			
Tentative Test for Quantity of Clay and Silt in Gravel for Highway Construction (D 72 - 20 T)	32	3	13
Tentative Test for Quantity of Clay and Silt in Sand for Highway Construction (D 74 - 20 T)	31	4	13
II. REVISIONS OF EXISTING STANDARDS RECOMMENDED FOR ADOPTION.			
Standard Test for Penetration of Bituminous Materials (D 5 - 16)	29	2	17
Standard Method for Determination of Softening Point of Bituminous Materials other than Tar Products (D 36 - 19)	31	1	16
III. PROPOSED NEW TENTATIVE STANDARDS.			
Proposed Tentative Specifications for Calcium Chloride for Dust Prevention	29	0	19
Proposed Tentative Specifications for Asphalt Cement, 40 to 50 Penetration	28	4	16
Proposed Tentative Specifications for Asphalt Cement, 50 to 60 Penetration	26	5	17
Proposed Tentative Specifications for Asphalt Cement, 60 to 70 Penetration	26	5	17
Proposed Tentative Specifications for Asphalt Cement, 70 to 90 Penetration	26	5	17
Proposed Tentative Specifications for Asphalt Cement, 90 to 120 Penetration	25	6	17
Proposed Tentative Specifications for High-Carbon Tar for Surface Treatment, Cold Application	26	1	21
Proposed Tentative Specifications for Low-Carbon Tar for Surface Treatment, Cold Application	27	0	21
Proposed Tentative Specifications for High-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product)	26	0	22
Proposed Tentative Specifications for Low-Carbon Tar Cement for Use Cold in Repair Work (Cut-Back Product)	26	0	22
Proposed Tentative Specifications for High-Carbon Tar for Surface Treatment, Hot Application	27	0	21
Proposed Tentative Specifications for Low-Carbon Tar for Surface Treatment, Hot Application	27	0	21
Proposed Tentative Specifications for High-Carbon Tar Cement	27	0	21
Proposed Tentative Specifications for Low-Carbon Tar Cemen	27	0	21
Proposed Tentative Specifications for Coal-Tar Pitch for Block Filler	22	5	21
Proposed Tentative Method of Test for Ductility of Bituminous Materials	30	1	17
Proposed Tentative Method of Test for Water in Bituminous Materials	31	0	17

This report has been submitted to letter ballot of the committee, which consists of 48 members, of whom 35 voted affirmatively, 1 negatively, and 12 have refrained from voting.

Respectfully submitted on behalf of the committee,

A. H. BLANCHARD,
Chairman.

PRÉVOST HUBBARD,
Secretary.

EDITORIAL NOTE.

The Tentative Test for Quantity of Clay and Silt in Gravel for Highway Construction and the Tentative Test for Quantity of Clay and Silt in Sand for Highway Construction referred to in this report were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on August 20, 1921, and appear in the 1921 Book of A.S.T.M. Standards.

The proposed revision of the Standard Test for Penetration of Bituminous Materials and of the Standard Method for Determination of Softening Point of Bituminous Materials other than Tar Products were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The methods of test as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The fifteen proposed tentative specifications and the two methods of test referred to in this report were accepted for publication as tentative and appear on pages 679–707.

REPORT OF COMMITTEE D-5
ON
COAL.

The activities of Committee D-5 on Coal during the present year have been largely devoted to reorganization and planning future work. Five years of comparative inactivity has made it rather difficult to get started on a constructive program. The tremendous demands on the coal-producing capacity of the country during and subsequent to the war created a condition under which it was quite impossible to develop standard specifications for the purchase of coal. With the cessation of this abnormal demand in the last six months, the prospect for a return to more settled methods in the purchase of coal has become much brighter. The committee believes that progress can be made in the formulation of specifications during the coming year.

Committee D-5 held one meeting in the past year, at which the appointment of the following three sub-committees was authorized:

Sub-Committee I on Methods of Testing.
Sub-Committee II on Nomenclature and Definitions.
Sub-Committee III on Gas Coals.

Sub-Committee I on Methods of Testing:

A. C. Fieldner, *Chairman.*

S. W. Parr	F. R. Haas
S. S. Voorhees	A. G. Blakeley
H. C. Dickinson	Solvay Process Co. (W. B. Hicks).

This sub-committee is part of a joint committee with a committee of the American Chemical Society on the subject of methods for laboratory sampling and analysis of coal, and takes over the work of Committee D-3 which has been discontinued as a separate standing committee.

Sub-Committee II on Nomenclature and Definitions:

Horace C. Porter, *Chairman*

S. W. Parr	W. D. Langtry
Alfred H. White	J. S. Burrows

O. O. Malleis

Organization of this sub-committee was completed during the latter part of the year, and work is in progress on the Use Classification of Coal and the definitions of terms used in such classification.

Sub-Committee III on Gas Coals:

Alfred H. White, *Chairman.*

American Gas Association		Am. Soc. Test. Mats.
J. F. Wing	W. R. Addicks	F. R. Hass
C. E. Lewars	J. H. Rose	F. R. Wadleigh

This sub-committee is part of a joint committee with a committee of the American Gas Association on Specifications for Gas Coals.

Committee D-5 has approved the recommendations of the sub-committee on testing (formerly Committee D-3) and recommends that the tentative revision of the Standard Methods for Laboratory Sampling and Analysis of Coal (D 22–16) in reference to the use of the Bureau of Standards Standard Screen Scale, which has been published as tentative for one year,[1] be referred to letter ballot for adoption as standard.

In last year's report, Committee D-3 recommended that the Tentative Method for the Determination of Fusibility of Coal Ash (D 22–19 T) be continued as tentative,[2] for the reason that a new and apparently shorter method used in the laboratories of the United Gas Improvement Co. was proposed to the committee for investigation. Unfortunately, on account of the difficulty in securing the necessary parts for the construction of the apparatus for this new method, the three cooperating laboratories who are investigating the new method were unable to complete their work in time for this report. The investigation is now in progress and it is hoped to have sufficient data available for the committee to make definite recommendations next year. It is therefore recommended that the present Tentative Method for the Determination of the Fusibility of Coal Ash be continued as tentative for another year.

This report has been submitted to letter ballot of the committee which consists of 26 members, of whom 21 have voted affirmatively, none negatively, and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER, *Chairman.*

EDITORIAL NOTE.

The proposed revision of the Standard Method for Laboratory Sampling and Analysis of Coal in reference to the use of the Bureau of Standards Standard Screen Scale Sieve, presented in 1920, was approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The methods of sampling as thus revised appear in the 1921 Book of A.S.T.M. Standards.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 822 (1920).

[2] *Ibid.*, p. 796.

REPORT OF COMMITTEE D-6
ON
COKE.

Committee D-6 held one meeting in the past year. The membership has been enlarged by the appointment of new members who are especially qualified for work on physical specifications for blast furnace coke. A sub-committee on this subject is now being organized and tentative methods for conducting shatter tests and hardness tests are in preparation for trial tests by the committee.

It is recommended that the tentative revision, with respect to using the Bureau of Standards Standard Screen Scale, of Standard Methods for Laboratory Sampling and Analysis of Coke (D 37 – 18), which has been published as tentative[1] for one year, be referred to letter ballot for adoption as standard.

At the suggestion of Committee E-8, consideration was given to nomenclature and definitions of terms relating to coke, as used in Standard Specifications for Foundry Coke (D 17 – 16) and Standard Methods for Laboratory Sampling and Analysis of Coke. It is recommended that these definitions, appended hereto,[2] be accepted for publication as tentative.

This report has been submitted to letter ballot of the committee which consists of 17 members, of whom 12 have voted affirmatively, none negatively, and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

RICHARD MOLDENKE,
Chairman.

A. C. FIELDNER,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Methods for Laboratory Sampling and Analysis of Coke presented in 1920 were approved at the annual meeting and adopted by letter ballot of the Society on August 20, 1921. The methods of analysis as thus revised appear in the 1921 Book of A.S.T.M. Standards.

The proposed Tentative Definitions of Terms Relating to Coke, referred to in this report, were accepted for publication as tentative and appear on pages 708–710.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 822 (1920).

[2] See p. 708.—ED.

REPORT OF COMMITTEE D-7
ON
TIMBER.

The report of Committee D-7 is presented in two parts: namely, Recommendations with reference to revisions of specifications and progress reports of sub-committees.

RECOMMENDATIONS WITH REFERENCE TO REVISIONS IN SPECIFICATIONS.

Standard Specifications for Yellow-Pine Bridge and Trestle Timbers (D 10 - 15).[1]—The committee recommends a slight change in the wording of the definition for dense southern yellow pine as given in the present standard specifications. The definition now reads "dense southern yellow pine shall show on either end an average of at least six annual rings per inch, etc." The clauses "on either end" and, "or else the greater number of the rings shall show at least one-third summer wood," have given rise to a good deal of misunderstanding and in order to clarify the intent of the specification the committee recommends that for these words there be substituted the words "on one end or the other," making the clause read, "Dense southern yellow pine shall show on one end or the other an average of at least six annual rings per inch and at least one-third summer wood, all as measured over the third, fourth and fifth inches on a radial line from the pith, etc."

This recommendation for revision has been submitted to letter ballot with the following results: Affirmative, 25; negative, 0; not voting, 10.

Revision of Tentative Specifications for Structural Douglas Fir (D 23 - 20 T).[2]—The committee finds that in the printing of the tentative specifications a typographical error occurred in Section 21. The standard size allowance is given as $\frac{1}{2}$ in. This should read $\frac{1}{4}$ in., making the revised clause read: "Rough timbers shall be sawed to standard size and when green shall not be more than $\frac{1}{4}$ in. less than the nominal size specified."

This recommendation for revision has been submitted to letter ballot with the following results: Affirmative, 25; negative, 0; not voting, 10.

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[1] 1918 Book of A.S.T.M. Standards.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 704 (1920).

Reports of Sub-Committees.

Sub-Committee III on Pacific Coast Timbers.—The work assigned to Sub-committee III for this year was to watch shipments made under the density and structural rules tentatively adopted by the Society in 1920, and to test them out by measurements at points of shipment and points of receipt as a basis of changes which should be made.

It was found that very little material is purchased or sold under density and structural grading rules, either in the South or in the West. It was found further that when a purchaser made an inquiry on density and structural rules that he encountered reluctance to sell on this basis and was actually offered material so nearly the equivalent, under some modification of the standard rules, that he was glad to accept the material offered at a lower price and congratulated himself on the saving in cost, while the few manufacturers who offered material under the density and structural rules met so much competition in something nearly as good that they could not get the business.

Such rules, while the most logical basis for material in which the strength properties are of importance, and while actually not differing materially from standard grades, are seemingly radically different and can be put into practice generally only by the concerted efforts of the seller and general demand of the buyer, and this has not occurred on the part of either. The solution would appear to be a campaign of education in regard to the rules, or the gradual introduction of their essential requirements into the standard grades.

The West Coast Lumbermen's Association, recognizing the importance of the matter, has during the past year given it very careful study, resulting in a decision that the most practicable steps in the matter are to recognize the most essential provisions of the grades in standard rules, with the rules tentatively accepted last year the ultimate goal.

As the result, in a revision of standard grading rules now under consideration by the West Coast Lumbermen's Association, new and additional grades of Selected Common Square Sizes, Posts, Columns and Caps, and Selected Common Stringers, Beams, Joists, etc., are proposed, prohibiting shake and cross or spiral grain and requiring medium rate of growth, with very coarse-grained pieces, either boxed heart or side cut, excluded, and with sound knots, if not in clusters, permitted in square sizes if not exceeding in diameter one-sixth of the width of the face in which they appear, and in stringer sizes if not exceeding $1\frac{1}{2}$ in. in diameter on edges or corners of wide faces, and being allowed to increase in diameter to a maximum size of 3 in. along the center lines of the wide faces.

In these rules there is no summer wood requirement, but, while there is no definite relation between rate of growth and percentage of summer wood, there is in Douglas fir a marked association, such that in material of medium rate of growth, which would be interpreted to mean material in which in any one inch there was not less than six, nor more than thirty, annual rings, a large majority of the pieces would have one-third or more summer wood, while the remainder would not have materially less. In other requirements these rules are even more rigid than the structural rules themselves.

Because of the study being made by the Lumbermen's Association, meetings of the sub-committee were not called until the results of the Lumbermen's Association's investigations were available for consideration. A meeting of the Pacific Coast members of the sub-committee was held in Seattle on March 12 and a meeting of the eastern members in Chicago on April 1. At both of these meetings the rules tentatively adopted by the Society in 1920 were discussed and it was decided that no changes were advisable at this time, but that these rules should be continued as tentative, and that conditions as above noted should be reported to the Society as indicating the progress in the matter.

It is undoubtedly the purpose of the Society that its specifications be as practicable as possible, and the sub-committee recommends therefore, that the study of the matter be continued and that every practicable means be adopted to educate the manufacturer and the purchaser of timber in its properties and essential requirements for particular uses, accepting the tentative rules as at present the best expression of these requirements.

Sub-Committee VII on Interpretation of Timber Tests.—This sub-committee was organized during the present year and herewith presents a brief progress report. Timber tests have been carried on in the United States for a good many years, resulting in a mass of data the correlation of which seems eminently desirable at this time. The sub-committee has gone over an enormous mass of material and herewith presents as information a brief historical statement together with certain fundamental considerations as to working stresses in structural timber. It is proposed to continue this work, looking forward to a definite analysis and correlation of the data so far available.

In order to properly interpret the strength data given in the various publications dealing with tests of timber it is necessary to know something of the selection of the material, the size, grade, and the condition of the test specimens and the purpose for which the various series of tests were made. Much of the data on strength of timber which appears in the various handbooks is taken from the Tenth Census Report. The tests of this material were made at the Watertown Arsenal between the years 1881 and 1884. The material was selected by Charles S. Sargent. Four specimens were taken from the butt of each tree. The specimens were 4 cm. square and were tested on a span of 1 m. The material tested was in an air-dry condition but no moisture determinations were made, so it is impossible to correctly interpret the data since the exact conditions of storage are not known, and the moisture content of air-dried material frequently varies sufficiently to materially change the strength values. The specimens being selected as they were from the butt of the tree offered wide variations in strength values, since it is well established now that the butt is the most variable portion of any tree. The work was done with the idea of giving a very superficial estimate of the value for various specimens. The tests are too few in number for the data to give more than a rough indication of the properties of the wood from a given species.

The next series of timber tests of importance was a series conducted at St. Louis under the supervision of Professor J. B. Johnson. These tests were made during the period some three or four years previous to 1893. A very broad outline of the research which was undertaken at that time is given in Bulletins Nos. 6, 8, and 12, entitled "Timber Physics, Part I, Preliminary Report," "Timber Physics, Part II, Progress Report, Results of Investigations on Longleaf Pine," and "Timber Physics, Economical Designing of Timber Trestle Bridges," respectively. This work was carefully planned and offered considerable possibilities. The work, however, was discontinued and the records of the tests were lost. The test specimens were 4 by 4 in. in cross-section and 60-in. span. The specimens contained the defects as found in the trees. Since all record of the defects in individual specimens have been lost it is impossible to make the fullest use of these data, although the bulletins published giving the outline of their work and their conclusions have been of great importance in formulating the present work on timber testing.

In about 1902, the present work on timber testing was begun and for the last 15 years there has been considerable work carried on by the Forest Service at all times. The planning and direction of these tests at the outset and for several years thereafter were under the direction of Dr. W. K. Hatt (see *Proceedings,* Am. Soc. Test. Mats., Vol. III, p. 308 (1903)). In the beginning of this work it was divided amongst a number of schools and at various times United States

Government timber testing stations have been located at Yale University, Purdue University, University of California, University of Colorado, University of Oregon, University of Washington, and University of Idaho. Tests were also carried on at Philadelphia, Washington, and Charleston, S. C.

Most of the strength tests, aside from those on special forms of manufactured articles, have been on railway bridge stringers and small clear pieces. A very common size for bridge stringers has been 8 by 16 in. and 16 ft. long. The standard small clear specimen tested in bending has varied somewhat but in the main has been 2 by 2 in. in cross-section and 30 in. long, tested over a span of 28 in. The tests of bridge stringers were made for a variety of purposes. A rather comprehensive series of tests was made on southern yellow pine ranging from the clear stock to some of the most defective in order to arrive at the influence of defects on strength. A number of tests of Southern pine were made for the purpose of determining the influence or preservative treatment on strength. Still others were made in order to check up the influence of density on strength of structural timber and to aid in the formulation of a density classification for Southern pine.

The tests of Douglas fir were likewise made for a variety of purposes, one of the important features being the checking up of the efficiency of grading rules at the time the tests were made. In the early tests of structural timbers, the beams were supported near the ends and loaded in the center. Later, the test was changed and two equal loads were applied at one-sixth of the span on each side of the center. The results of tests on structural timbers have been issued in a large number of publications; most of them, however, are summarized in Bulletin No. 108.

Much confusion has arisen by various people attempting to use the data in ways that were never intended. This is especially true when they undertake to compare species on the basis of these structural timber tests. The information is of exceeding great value in formulating grading rules, in determining the influence of defects and in getting the relation between the strength of large and small pieces, but the absolute values do not and can not represent the average strength of any grade of material of the species, as that average value is continually shifting, due largely to manufacturing conditions which at one time will throw into a grade timber of a high quality and at another time changes in demand will cause the same grade to carry a maximum of the poorest stock that will pass. This difficulty is also aggravated by the fact that most of the commercial grades now in use are not based on the size and distribution of defects such as insure any standard strength. It must also be considered that the tests made with the center load will always average higher for the same grade of material than the tests made with the two loads, since with the two loads the knots and other defects have a greater influence.

Aside from the Forest Service, various schools have made short series of tests, and some tests have been made by commercial concerns. Tests made by the Santa Fé Railway at their laboratory in Topeka are, it is believed, far more extensive than those made by any other organization outside of the United States Forest Service. For every test of structural timbers which has been made by the Forest Service several hundred tests have been made of small clear pieces. These tests are intended for a comparison of the species for obtaining the strength of the clear wood and the factors which influence their strength. A careful study of these test data, together with a study of the tests of structural timbers to find the influence of defects, can be made to closely predict the strength of structural timbers of any species and with any prescribed defects.

The results of tests of small clear pieces have been published to a certain extent along with the tests of the bridge stringers. Two rather comprehensive tables have been published as United States Department of Agriculture Bulletin No. 556. In the use of this bulletin it is important that the engineer and architect read carefully the text, for, while the text appears simple, it contains explanations of many of the variations and the strength data which would otherwise be confusing. Bulletin No. 556 contains by far the largest collection and most authentic strength data yet published.

Working Stresses in Structural Timber.—The committee offers the following comments in regard to working stresses in structural timber:

1. It is well determined that the strength of a particular piece of timber is in a measure determined by the condition under which it is used. From the tests it is seen that increase in moisture decreases the strength of timber, therefore it must be determined, first, in designing a particular structure, what the moisture conditions are.

2. It is also well determined by the tests that resistance to suddenly applied loads is much greater than to slowly applied or constant loading; therefore the condition of loading will affect the amount of allowable stress.

3. Warning of failure of a piece of timber in a structure is usually given a considerable time in advance of actual failure; therefore, when efficient inspection is had this feature gives an element of safety in older structures.

While there is no well-defined "elastic limit" in timber tests, there is in general a region where the proportionality of stress to strain ceases to be constant. It is therefore well to keep stresses well within this limit. Timber, however, does recover from high stresses; therefore its resistance to quick loading.

From the above it will be seen that in order to have a rational design it is necessary to state working stresses of different amounts for different kinds of loadings and exposure of the timber. As an example, for dense structural yellow pine, the maximum working stress will be 1100 lb. per sq. in. This is for constant loading and for submerged locations where the timber is constantly wet. In locations in the weather, such as bridges, the allowable working stress for constant loading is 1400 lb. per sq. in. Under cover, where the timber is always dry, the allowable working stress for constant loading is 1600 lb. per sq. in.

From the tests, it is determined that the resistance of timber is approximately proportional to the speed of loading. For constant loading, the stresses above given are proper, but for sudden loading, resulting in 100 per cent impact, the successive loadings being far enough apart so as to allow reasonable recovery of the timber, the allowable stresses may be doubled (not to exceed 2800 lb. per sq. in.), the stresses due to this sudden loading being those actually computed from the load with the impact. For other proportions of impact, less than 100 per cent, the allowable working stress may be increased in a ratio equal to the percentage of impact. For dense structural yellow pine, the allowable working stresses would, therefore, be as follows:

1. For wet or submerged locations.......1100 + 1100 *I* lb. per sq. in
2. For exposed locations (bridges).......1400 + 1400 *I* " "
3. For constantly dry locations.........1600 + 1600 *I* " "

where *I* is the proportional impact stress.

Sub-Committee IX on Methods of Testing.—This sub-committee reports progress as follows:

Since the organization of Sub-Committee IX, work has been progressing on the preparation of standard methods for testing wood. In this work it has been necessary to keep in mind the methods of testing which have been used in making the half million tests already completed by the United States Forest Products Laboratory, and the like procedure which has been adopted by other institutions, such as the Forest Products Laboratory of Canada, the Indian Forest Service of Dehra Dun. Standard methods will first be prepared for the testing of small clear specimens, which will be followed by procedure for the testing of timbers in structural sizes.

This report has been submitted to letter ballot of the committee, which consists of 35 members, of whom 25 have voted affirmatively, none negatively, and 10 have refrained from voting.

Respectfully submitted on behalf of the committee,

HERMANN VON SCHRENK,
Chairman

J. A. NEWLIN,
Secretary.

REPORT OF COMMITTEE D-9
ON
ELECTRICAL INSULATING MATERIALS.

The work of this committee was seriously curtailed during the war period and for some time immediately thereafter, but during the past year the committee activities have been revived and two meetings have been held excluding the one held at the annual meeting of the Society last June. These meetings were both held in New York, one on January 24, 1921, and the other on March 25, 1921.

Since its inception, the committee has confined its work entirely to the testing of insulating materials as the state of the art does not as yet warrant the establishing of specifications for the various materials themselves. Tests and procedures for each of five classes of insulating materials have been studied by as many sub-committees and the work of the committee during the past year can be best reported by briefly indicating the work of each of these sub-committees.

Sub-Committee I on Insulating Varnishes.—Several drafts of standard tests for insulating varnishes have been considered during the past few years. Finally during the past year, after two meetings of the sub-committee and a special conference between the representatives of three of the more important companies particularly interested in the matter, a standard has been agreed upon. The committee now recommends that the appended Proposed Tentative Methods of Testing Insulating Varnishes[1] be accepted for publication as a tentative standard.

Sub-Committee II on Molded Insulating Materials.—The only standards which have been offered heretofore to the Society by Committee D-9 are the Tentative Tests for Molded Insulating Materials (D 48 - 17 T).[2] This standard has now been published as tentative for four years and during that period no important criticism has been received. It is understood that these tests are now in more or less general use by the manufacturers of this class of insulating material. They have also been adopted as standard by the Associated Manufacturers of Electrical Supplies. It was expected to recommend at this time that these tentative tests be advanced to standard, but some developments since the March meeting of the committee relative to the specimen for dielectric strength tests indicate the desirability of a change. It is therefore recommended that these tests be continued as tentative with, however, certain minor changes, most of the more important of which are as follows:

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[1] See p. 722.—Ed.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 776 (1920).

1. *Number of Specimens.*—The advance of the art since these tests were first prepared has resulted in a more uniform product so that fewer specimens need be subjected to each of the various tests.

2. *Room Temperature.*—The present tentative standard gives the room temperature as about 21° C. (70° F.). This has been changed to 20° C. (68° F.) to conform to the more usual practice.

3. *Pad in Compressive Test.*—The present tentative standard prescribes sheet lead, $\frac{1}{16}$ in. thick, as a pad between the specimen and the testing heads. Experience has shown that this material is unsatisfactory because since it flows under load, there is more movement of the lead at the edges than at the center with the result that the equivalent of an uneven loading surface is produced and failure occurs by a wedging action. In the revision, lead has been replaced by a "sheet of soft annealed copper $\frac{1}{32}$ in. thick or heavy blotting paper."

4. *Direction of Loading.*—A clause has been added prescribing that in the compressive and transverse tests these specimens shall be tested in a direction which is at right angles to that in which the pressure was applied in molding the material. In other words, it is prescribed that the tests shall be made in the weakest direction.

5. *Span in Transverse Test.*—A minimum limit on the spacing between supports has been added in addition to the maximum limit.

6. *Size of Transformer.*—The minimum size permitted by the present tentative standard is 5 kva. This has been reduced to 2 kva. for potentials up to 50,000 volts, but the limit is kept at 5 kva. for potentials greater than 50,000 volts.

Sub-Committee III on Sheet Insulation.—This class of insulating material is very large because it is used on all types of electrical apparatus. While there are several important properties to be considered, the dielectric strength is probably the most important and this sub-committee has so far devoted its attention entirely to the procedure for making such tests—particularly since standardization in that direction seemed most urgent.

The apparent dielectric strength of a material is greatly affected by the time of application of the testing potential due to the generation of heat in the specimen so that two types of tests are desirable: one, to give the dielectric strength under a rapidly applied potential or so-called apparent "momentary" dielectric strength, and the other to give the dielectric strength under continuous application of potential. This latter test involves difficulties because of the effect of the thermal capacity of the electrodes and the effect of any local ionization of the air which not only causes local heating but may also cause local chemical action. The test cannot of course be made under oil because that would change thermal conditions entirely. Thus, it is necessary to give careful attention to the electrode arrangements.

The sub-committee presented to the main committee some preliminary suggestions for a standard procedure for these tests but while it was possible to get agreement on some important details, such, for example, as the size of the electrodes to be used in this class of work, it was found that more study was necessary before the details of this "time" test could be agreed upon. However, with some experimental work and the study of electrode arrangement, it is confidently expected that a procedure will be offered for consideration at the next annual meeting of the Society.

As a matter of interest, it may be stated that the committee has agreed on the general type and size of electrodes for the "momentary" test: namely, circular polished brass or copper disks, 4 in. in diameter. Experiment has shown that the apparent dielectric strength under short time applications of potential decreases greatly as the area of flat electrodes is increased, being most marked in the case of thin sheet materials. With circular disk electrodes, the apparent dielectric strength is very nearly a minimum when a diameter of 4 in. is reached.

Sub-Committee IV on Liquid Insulations.—One of the greatest needs in the testing of this class of materials has been the standardization of the electrodes and the length of gap used in testing oils intended for high tension transformers and switches. A great variety of electrode sizes and spacings has developed in the industry, leading to much confusion. Furthermore, there had been no comprehensive investigation of the relation between these various apparatuses so that no comparison could be made between tests made by the different methods.

About four years ago this sub-committee inaugurated an extensive, thorough-going investigation of the subject of potential tests of transformer oils, with the primary object of settling on the best electrode arrangement used for this work and the determination of the factors to be employed to convert the results obtained with one electrode arrangement to each of the other more common ones. This investigation, which included over 2100 separate tests, obviously involved a great deal of work, particularly the analyzing of the great mass of test data obtained. The work was of course interrupted by the war, but it has now been completed and a report of the investigation is given in Appendix I. The committee desires to record its appreciation of the services rendered by the three organizations who cooperated in the work: namely, the Bureau of Standards, the Vacuum Oil Co. and the Westinghouse Electric and Manufacturing Co. The committee is under particular obligation to Dr. F. B. Silsbee of the Bureau of Standards who analyzed the data and prepared the report in Appendix I.

This important matter of a proper procedure for dielectric strength tests of oil having been settled by this investigation, a specification for testing such oils has been prepared and is appended hereto under the title Proposed Tentative Methods of Testing Transformer and Switch Oils.[1] It is recommended that these methods be accepted for publication as a tentative standard.

The matter of a sludging test for these oils has been given particular attention by the sub-committee. It was hoped that a sludging test procedure could be included in the proposed tentative tests, but the committee feels that none of the methods in common use is entirely satisfactory. Certain new methods are being investigated and this, together with some original work which may be undertaken, ought to place the committee in position to make a definite recommendation next year.

As the sludging characteristic of transformer oils is being given considerable attention at this time, the procedures for the methods in most general use are given in Appendix II together with that for another method which has been suggested and which the sub-committee proposes to investigate.

Sub-Committee V on Porcelain Insulation.—This sub-committee has been studying this subject for several years and a series of tests and test procedures were finally submitted to the main committee this year. These are appended hereto under the title Proposed Tentative Methods of Testing Electrical Porcelain[2] and the committee recommends that they be accepted for publication as tentative.

Work of the committee which is under way but not yet in shape to be reported upon includes (1) a procedure for dielectric strength tests of sheet insulating materials, (2) procedure for a sludging test of transformer and switch oils and (3) preparation of tests of molded insulation for high frequency applications.

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[1] See p. 737.—ED.

[2] See p. 727.—ED.

Subjects to which the committee expects to give its attention include (1) pothead and splicing compounds for underground cables, and (2) dielectric losses in insulating materials.

The following is the result of the letter ballot vote of the committee on the various recommendations made herein:

	AFFIRMATIVE.	NEGATIVE.	NOT VOTING.
Submission of Tentative Methods of Testing Insulating Varnishes	14	0	6
Submission of Tentative Methods of Testing Electrical Porcelain	11	1	8
Submission of Tentative Methods of Testing Transformer and Switch Oils	12	0	8
Revision of the Tentative Tests for Molded Insulating Materials (D 48 - 17 T)	11	1	8

This report has been submitted to letter ballot of the committee, which consists of 20 members, of whom 15 have voted affirmatively, none negatively and 5 have refrained from voting.

Respectfully submitted on behalf of the committee,

F. M. FARMER,
Chairman.

H. S. VASSAR,
Secretary.

EDITORIAL NOTE.

The proposed Tentative Methods of Testing Insulating Varnishes, the proposed Tentative Methods of Testing Electrical Porcelain and the proposed Tentative Methods of Testing Transformer and Switch Oils were accepted for publication as tentative and appear on pages 722–740.

The proposed revisions of the Tentative Tests for Molded Insulated Materials referred to in this report were accepted. The methods of testing as thus revised appear on pages 711–721.

APPENDIX I.

JOINT COMPARATIVE TESTS OF SPARK GAPS FOR TESTING TRANSFORMER OILS.

The tests described below were carried out in the spring of 1917 by the laboratories represented at that time on Sub-committee IV of Committee D-9 of the Society.

Object.

In the testing of transformer oils for dielectric strength, a number of different types of spark gap have come into general use, and this fact, together with the very wide variations in strength which were found when supposedly identical samples were tested, even in the same gap, emphasized the need for a more definite standardization of this test. The adoption as standard of that type of gap which should show the most desirable characteristics for oil testing was of course the primary purpose of the work. It was also very desirable that a common basis should be established by which the results of tests made with different types of gap could be inter-compared since this would obviate the necessity for scrapping much non-standard equipment now in use.

The objects of the tests were therefore to determine, first, the best representative value for the multiplying factors by which the results of dielectric strength tests of transformer oils made with any one of the usual types of spark gap can be converted into the values which would be obtained with any other type of gap; second, to determine the relative merits of the several types of test gap now in general use; and, third, to accumulate as much miscellaneous information as possible to throw light upon the causes of the very great variations in dielectric strength shown by successive tests on a supposedly homogeneous sample of oil.

Program of Test.

The bulk of the work consisted in parallel tests made at each of the three cooperating laboratories: namely, Vacuum Oil Co., Rochester, N. Y., Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa., and the Bureau of Standards, Washington, D. C. The oil to be tested was furnished through the courtesy of the Vacuum Oil Co., and consisted of four different grades of material, the properties of which are given in Table I. A 5-gal. can of each of the four kinds of oil was sent to each of the three laboratories, the samples to the various laboratories being as nearly identical as possible. Three styles of electrodes were used at each laboratory: (1) 1-in. disks placed with their axes horizontal, this type of apparatus being kindly furnished to the three laboratories by the General Electric Co.; (2) $\frac{1}{2}$-in. disks with their axes horizontal—this is the type of gap known as the "old G. E."; (3) $\frac{1}{2}$-in. spheres with their axes vertical—these gaps were furnished by the Westinghouse Co. and are known as "old Westinghouse." With each type of electrode, four spacings: namely, 0.05, 0.10, 0.15, and 0.20-in. were used. With each gap, spacing and oil, three fillings of the cup were made, and five "shots" were made on each filling. There are thus available 2160 observations in the entire mass of data.

In these tests the room temperature was kept as near 25° C. as conveniently possible and the oil containers were not opened except when they were at a temperature at least as high as that of the room. When changing from one oil to another, the testing vessel was rinsed with dry gasoline and then with a small quantity of the oil to be tested. At the Vacuum Oil Co. and the Bureau of Standards, a clean polished steel rod was wiped across the faces of the electrodes between shots and also before the first shot of each filling to remove possible accumulations of carbon. This procedure was not followed at the Westinghouse laboratory for fear of contaminating the oil. After filling the cups, sufficient time was allowed before the application of voltage to permit air bubbles to escape. A 60-cycle alternating voltage was applied and raised at an approximately uniform rate of 3000 (effective) volts per second, until breakdown occurred. The results are expressed in terms of the effective kilovolts of a sine wave having the same crest value as that at which breakdown occurred.

TABLE I.—PROPERTIES OF OILS USED IN TESTS.

OIL.	SPECIFIC GRAVITY.	VISCOSITY AT 40° C. (104° F.) (SAYBOLT TYPE C).	DIELECTRIC STRENGTH (1-IN. DISKS, 0.1-IN. GAP).
A	0.854	55 seconds	27 500 volts
B	0.867	100 "	26 400 "
C	0.829	34 "	33 400 "
D	0.860	74 "	30 500 "

It may be noted that the work at the Vacuum Oil Co. was done by the laboratory staff accustomed to the daily routine of oil testing. At the Westinghouse laboratory, the tests were made by skilled engineers who had had much previous experience in such work but were not at the time engaged in routine testing. At the Bureau of Standards, the work was done by a staff trained in delicate laboratory manipulation but not particularly accustomed to the precautions necessary in testing transformer oil.

In addition to the main program just outlined, special tests were made at the Bureau of Standards on the effect of oil circulation upon the observed dielectric strength of oil and at the Vacuum Oil Co. upon the temperature coefficient of the dielectric strength.

TABLE II.—SUMMARY OF BREAKDOWN VOLTAGES (R.M.S. KILOVOLTS) OF OIL GAPS.

Electrodes and Gap.		B. S.	Vac.	Wgh.	Mean.	B. S.	Vac.	Wgh.	Mean.
		OIL A.				OIL C.			
1-in. Disk	0.05	15.2	11.7	18.0	15.0	16.5	8.8	18.5	14.6
	0.10	23.6	23.2	35.8	27.5	33.5	25.9	40.7	33.4
	0.15	33.6	32.9	39.3	35.3	39.5	32.5	53.7	42.0
	0.20	40.6	39.1	53.8	44.5	50.8	39.8	64.8	51.8
½-in. Disk	0.05	21.2	15.3	22.2	19.6	27.1	20.0	24.9	24.0
	0.10	37.9	29.4	38.9	35.4	48.4	34.6	42.9	42.0
	0.15	48.7	38.9	47.5	45.0	48.8	42.3	57.9	49.7
	0.20	49 3	45.2	51.0	48.5	60.0	50.6	67.4	59.3
½-in. Sphere	0.05	23.6	23.6	29.5	25.6	33.4	26.3	32.9	30.8
	0.10	44.2	45.5	51.1	46.9	49.1	50.2	55.3	51.5
	0.15	61.1	....	67.1	64.1	67.1	....	....	67.1
	0.20	68.9	....	....	68.9				
		OIL B.				OIL D.			
1-in. Disk	0.05	15.2	8.9	14.3	12.8	16.8	11.0	17.8	15.2
	0.10	26.5	22.3	30.5	26.4	29.1	24.6	37.8	30.5
	0.15	36.3	32.2	42.8	37.1	38.5	30.9	48.7	39.4
	0.20	42.8	37.6	55.7	45.4	41.2	37.9	59.8	46.3
½-in. Disk	0.05	21.5	13.2	20.9	18.5	25.8	14.0	19.4	19.7
	0.10	37.1	24.8	38.7	33.5	41.0	26.9	40.7	36.2
	0.15	47.9	33.4	42.8	41.4	54.3	33.7	47.0	45.0
	0.20	49.8	46.1	54.9	50.3	55.5	42.5	52.8	50.3
½-in. Sphere	0.05	22.6	20.7	25.3	22.9	26.2	22.5	30.0	26.2
	0.10	38.5	35.2	48.6	40.8	50.1	43.8	56.4	50.1
	0.15	56.0	51.1	60.6	55.9	61.1	52.4	56.7	56.7
	0.20	70.5	....	....	70.5	72.5	....	....	72.5

RESULTS.

Table II gives a summary of the values of dielectric strength as observed by each laboratory for the various oils, electrodes, and spacings, and also the mean value for all three laboratories.

Table III gives the quotient of the breakdown voltage corresponding to the type of gap indicated at the head of the column divided by the breakdown voltage observed with the type of gap indicated at the side of the table. Each value in this table is the average of the twelve values of this quotient obtained by the three laboratories on the four different oils.

The three most generally used combinations of electrode and spacing are (1) 1-in. disks 0.1 in. apart, (2), ½-in. disks 0.2 in. apart, and (3) ½-in. spheres 0.15 in. apart. The ratios of breakdown voltage in these three gaps are tabulated in Table IV, the values being rounded for convenience in practical use. Fig. 1 is a plot showing the variation of breakdown voltage with gap length for each of the three different types of electrodes. The values plotted are the averages for the three laboratories and four oils.

DISCUSSION OF OBSERVED VARIATIONS FROM MEAN VALUES.

One of the most striking points in connection with these measurements is the very wide variation in the observed dielectric strength which occurs even between the successive "shots" on the same sample. The data available have been analyzed with a view to obtaining a quantitative expression for the magnitude of this effect under various conditions. In the following discussion, the variations are expressed in terms of the "probable error" which is computed by multiplying by 0.84 the average deviation of the individual values from the mean of any particular series.

TABLE III.—AVERAGE RATIOS OF BREAKDOWN VOLTAGES IN VARIOUS GAPS.

Electrode.	Gap. in.	1-in. Disk.				½-in. Disk.				½-in. Spheres.			
		0.05	0.10	0.15	0.20	0.05	0.10	0.15	0.20	0.05	0.10	0.15	0.20
1-in. Disk.	0.05	1.	2.10	2.76	3.36	1.46	2.62	3.24	3.79	1.91	3.45	4.12	4.39
	0.10	....	1.	1.32	1.60	0.70	1.26	1.57	1.80	0.91	1.64	2.07	2.69
	0.15	....	....	1.	1.22	0.54	0.96	1.19	1.37	0.66	1.24	1.58	1.96
	0.20	....	....	....	1.	0.46	0.79	0.98	1.13	0.57	1.03	1.30	1.70
½-in. Disk.	0.05	....	....	....	....	1.	1.81	2.25	2.62	1.32	2.39	2.98	3.11
	0.10	....	....	....	....	....	1.	1.24	1.44	0.73	1.32	1.63	1.83
	0.15	....	....	....	....	....	....	1.	1.16	0.59	1.00	1.34	1.40
	0.20	....	....	....	....	....	....	....	1.	0.51	0.91	1.16	1.38
½-in. Sphere	0.05	....	....	....	....	....	....	....	....	1.	1.81	2.31	2.93
	0.10	....	....	....	....	....	....	....	....	....	1.	1.29	1.61
	0.15	....	....	....	....	....	....	....	....	....	....	1.	1.19
	0.20	....	....	....	....	....	....	....	....	....	....	....	1.

Each entry in this table is the quotient obtained by dividing the breakdown voltage in the gap indicated at the top of the column by the breakdown voltage of the gap indicated at the left side of the table.

The first cause of variation, which we will indicate by x, is that which causes successive shots of a single filling to differ from one another. The data show that the average deviation of a single shot from the mean of five shots of the same filling is 8.5 per cent, this value being the average of 68 representative fillings chosen at random. It is roughly the same in all three laboratories. From this source of variation alone we would expect from the theory of errors that the probable error of the mean of five shots from the true value of the filling would be $0.84 \times \frac{8.5}{\sqrt{5-1}} = 3.6$ per cent.

The second source of variation, y, is the different contamination possibly present between successive fillings which would make the true value of the breakdown voltage of one filling different from that of another. The data show that the average deviation of the mean of one filling from the mean of all three fillings on the same sample of oil is 4.2 per cent, and hence from the theory of probability we might expect that a single filling would differ from the true value of breakdown voltage of the sample of oil tested by a probable error of $0.84 \times 4.2 \sqrt{3/2} = 4.3$ per cent. Of this 4.3 per cent, 3.6 per cent would result from the variation x referred to above and we may therefore conclude that variation y contributes only $\sqrt{4.3^2 - 3.6^2} =$ 2.2 per cent.

Considering the fifteen shots which contribute to the final mean, we find their individual probable error to be 9.2 per cent, which would indicate that the final mean should be accurate to $\frac{9.2}{\sqrt{14}} =$ 2.5 per cent. This probable error of 9.2 per cent is substantially constant among the three laboratories, the individual values being for the Bureau of Standards 10.0 per cent, the Vacuum Oil Co. 8.4 per cent, and the Westinghouse Electric and Manufacturing Co. 9.7 per cent. It may also be noted that this probable error was substantially the same for all oils and for all forms of electrodes. However, it was slightly larger with the shorter gaps, the values being as follows:

Table IV.—Ratios of Breakdown Voltages in Commercial Test Gaps.

	1-in. Disk 0.1-in. Gap.	½-in. Disk. 0.20-in Gap.	½-in Sphere 0.15-in. Gap.
1-in. Disk, 0.10-in. Gap	1	1.80	2.05
½-in. Disk, 0.20-in. Gap	0.55	1	1.20
½-in. Sphere, 0.15-in. Gap	0.50	0.85	1

Gap Length.	Probable Error of One Shot in 15.
0.05	11.3
0.10	8.4
0.15	8.1
0.20	7.9

A comparison of the results obtained in the different laboratories, however, shows a very large discrepancy between the values obtained at different places. The ratios of the values obtained at one laboratory to the mean of the values obtained at the three laboratories are on the average: Bureau of Standards : Vacuum : Westinghouse = 1.03 : 0.83 : 1.13. This discrepancy may result from any of the following causes, all of which however seem to be exceedingly improbable:

1. A constant error in the voltage measurements due to voltmeter error, transformer ratio, or to wave form.

2. A constant contamination of the oil in shipment. This is exceedingly unlikely since practically identical factors were obtained for all four oils, and the Vacuum Oil Co. results, the sample of which did not require shipment, are the lowest.

3. Some unexplained difference in procedure.

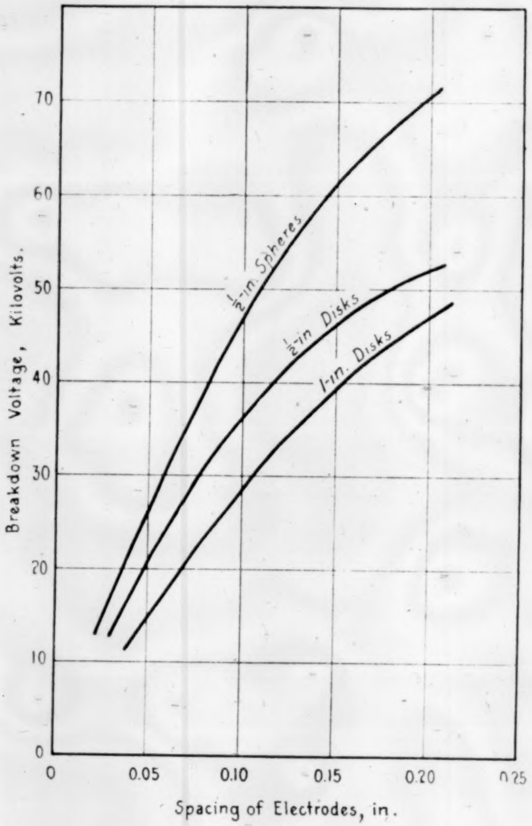

FIG. 1.—Dielectric Strength of Transformer Oils with Various Shapes of Electrodes.

In addition to the constant factor of discrepancy just discussed, there is an additional type of variation which may be denoted by z, which makes the values obtained at one laboratory somewhat irregular with respect to values bearing a constant ratio to those of the other two laboratories. Thus, one of the 48 final mean values of breakdown voltage has a probable error of 5.8 per cent from the mean of the corresponding value for the three laboratories even after allowing for the constant difference by the corresponding factor listed above. From the variations x and y alone, we should expect the mean of the three laboratories to be correct to $\frac{2.5}{\sqrt{3}} = 1.4$ per cent, and consequently the average deviation of a single mean from this to be $2.5\sqrt{4/3} = 2.9$ per cent. Consequently the variation z must produce $\sqrt{5.8^2 - 2.9^2} = 5.0$ per cent. In the mean of 48 trials (of 15 shots each) the random variation of 5.8 per cent due to causes x, y, and z would produce a probable error of $\frac{5.8}{\sqrt{48}} = 0.8$ per cent, which therefore cannot begin to account for the constant discrepancies of 3, 17 and 13 per cent between the respective laboratories.

In computing the values of ratio given in Table III, these constant differences cancel out and from variations x and y alone we would expect any one average ratio to have a probable error from its true value of only 3.5 per cent. With variation z also present, this would be increased to $5.8\sqrt{2} = 8.2$ per cent. The observed probable error of a single ratio from the mean of the 12, which is listed in Table III, is 8.6 per cent, and from the mean of the four values of ratio obtained in the same laboratory is 6.4 per cent, which indicates that the variation z is present even in the results obtained at a single laboratory and is only in part, at least, caused by the differences in procedure in the different laboratories. It may result from (1) error in setting the length of gap, (2) contamination resulting from the necessary handling of the electrodes, and (3) to stray contamination during the longer interval which elapses between the different tests as compared with the contamination indicated by variation y, which occurs merely between immediately consecutive fillings.

We must conclude, therefore, in summarizing this discussion, that the final mean values of ratios in Table III are accurate to a probable error of $8.6/\sqrt{12} = 2.5$ per cent. One voltage measurement based upon 15 shots distributed among three fillings, such as those tabulated in Table III, may be regarded as accurate to 2.5 per cent if variations x and y only are considered, to 5.8 per cent if variation z is also considered, and to 12 per cent if the constant discrepancy between the laboratories is included.

DESIRABLE NUMBER OF SHOTS PER FILLING.

It is sometimes maintained that only a single shot should be made with each filling of the test vessel because of contamination of the sample by the carbon resulting from the electric arc. To investigate this point, the ratio of the mean of the three first shots of each group of 15 was compared with the mean of the entire 15 shots of each of the 144 groups of fillings. The first shot was found to be on an average 5 per cent higher. To determine whether or not the first shot was more repeatable, the probable error of the three first shots of each group from their own mean for all the 144 groups was computed and found to be 7.4 per cent while the probable error of the individual shots from the mean of the entire 15 of each group was 9.2 per cent. The ratio of these errors is 0.80 while that which would be indicated by the theory of probabilities, if there is no physical difference between the first shots and the succeeding shots, is $\sqrt{\frac{10}{14}}=0.85$. This agreement indicates quite strongly that the contamination of the oil by the products of carbonization resulting from the first shot is negligible in its effect upon the accuracy of the results.

The question of how many shots to take from a single filling is, therefore, to be determined entirely by the relative length of time required to make a shot and to refill the testing vessel, and by the possibility of contaminating a single filling of oil while pouring it from the container to the testing cup. It may be shown that if t = time required to make one shot and T = time required to make a fresh filling, and if p = probable error of a single shot from the mean of all shots on one filling, and P = probable error of mean of one filling from mean of all fillings, then the time of the observer is most economically spent if the number of shots per filling is $n=\left(\frac{T}{t}\;\frac{p^2}{P^2}\right)$[1]. According to this formula, if variations x and y only are present, it is most economical of time to take as many as 15 shots on a single filling. It is probable, however, that the danger of contaminating a single filling is appreciable and that a smaller number, such as the five shots used in these tests, is on the whole more desirable.

EFFECT OF CIRCULATION.

To investigate any possible effect of circulation of oil upon the observed dielectric strength, two series of observations were carried out at the Bureau of Standards. The first of these was made in a test gap having spheres $\frac{1}{2}$ in. in diameter spaced 0.1 in. apart. A glass tube, 1.5 cm. in internal diameter and 3 cm. long, could be slid over the gap or pushed to one side, as desired. Samples of oil *A* were tested in this gap, the shots being taken in pairs: *i. e.*, two with tube off, then two with tube on, etc. Fifty-seven shots in all were taken, 29 with the tube on and 28 with tube off. These shots were distributed among five fillings of the cup. The average voltage with tube off exceeded that with the tube on by only 5.4 per cent. The probable error of either mean value was about 2.2 per cent.

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[1] This relation was deduced by M. D. Hersey in some as yet unpublished work on the theory of errors.

In the second arrangement, a funnel was set up so as to deliver a vertical jet of oil having a diameter of about 4 mm. and a velocity of about 100 cm. per second. Two platinum wires of 0.1 mm. in diameter sealed into glass tubes were immersed in the jet so as to leave a spark gap of about 0.04 in. long. Then 118 shots were taken between these electrodes alternately while in the jet and while immersed in a beaker of still oil. The supply of oil in the funnel and beaker were replaced three times in the course of the experiment. The average breakdown voltage in the still oil exceeded that in the jet by 2.5 per cent, while the probable error to be expected for the mean value under either condition was about 1.7 per cent. It can consequently be concluded that the presence of a velocity as great as 1 m. per sec. does not appreciably affect the dielectric strength of the oil.

TEMPERATURE COEFFICIENT.

The following experiments were carried out at the Vacuum Oil Co. to determine the temperature coefficient of dielectric strength of typical transformer oil:

A sample of each of the four grades of oil was tested for dielectric strength at average temperatures of 45, 20, 10, 6 and 0° C. Decreases in dielectric strength followed decreases in temperature at a reasonably constant rate although the plotted curves were not smooth. The conclusion from the series of tests is that about 0.13 kv. per degree is a reasonable correction for deviation from 25° C., the correction being subtracted when the temperature is above 25° C. and added when the temperature is below 25° C.

CONCLUSIONS.

From the experiments described above, the following conclusions may be drawn with some degree of certainty:

1. The gap between 1-in. disks with horizontal axes is to be preferred because of the lower values of breakdown voltage and hence smaller testing equipment required.

2. Spacings of less than 0.1 in. are undesirable because of the greater probable error of measurement made with such small gaps.

3. The results of measurements obtained with other forms of gap may be referred to the recommended standard gap by the factors tabulated in Table IV.

4. The value of dielectric strength obtained from the first shot of each filling does not differ sufficiently from the values given by later shots in either its magnitude or repeatability to justify the practice of making only one shot on each filling.

5. A precision of approximately 3 per cent may be expected in the mean value of 15 shots distributed over three fillings, provided no adjustment of length of gap is made. Uncertainties of 6 per cent may be introduced as a result of resetting the electrodes and from contamination introduced from day to day at a single laboratory. Differences as great as 12 per cent may arise even in careful work done at the different laboratories.

6. The circulation of oil past the electrodes does not appreciably affect the observed values of dielectric strength.

7. The temperature coefficient of the dielectric strength is approximately 0.13 kv. per 1° C.

APPENDIX II.

PROCEDURES IN SLUDGING TESTS FOR TRANSFORMER OILS.

Methods of procedure for determining the sludging characteristics of transformer oils are given as follows:

German "No. 9" Test (used extensively abroad).—The following is translated from the German:

Two hundred cc. of oil are heated continuously for 70 hours at a temperature of 120° C. in an Erlenmeyer flask of 400-cc. capacity, submerged in an oil bath. At the same time oxygen gas is passed through at a rapidity of two bubbles per second. To ascertain the tar percentage, 50 g. of this oil are then heated for 15 minutes with a solution of 50 per cent by weight of alcohol and 4 per cent of NaOH in an Erlenmeyer flask furnished with a reflux condenser and placed in a boiling water bath. The mixture is then vigorously shaken for 15 minutes. (The flask should be wrapped in a cloth, placed on a table and whirled.) The mixture is then poured into a separatory funnel and left over night, after which it is filtered into another separatory funnel. This alcoholic solution is then acidified with HCl (sp. gr. 1.12) until no further change takes place in the color. The tar is removed with 90 cc. of benzol. Separate and draw off the acid layer. The mixture of benzol is then twice washed with water and transferred to a glass evaporating dish. The separatory is washed out once with benzol and once with alcohol, these washings being added to that in the evaporating dish. Evaporate to dryness, weigh the residue and calculate the percentage by weight.

Michie Test.—This method and modifications of it have been used several years. The following is one procedure:

Put 100 cc. of oil into a clean, dry, round-bottom flask having a neck 11 to 12 in. long, $\frac{3}{4}$ in. in internal diameter, the bulb being $2\frac{3}{4}$ to 3 in. in diameter and with a capacity of 200 cc. A piece of pure sheet copper 51 by 32 by 0.01 mm. is burnished bright, is rolled so that the ends slightly overlap and small enough so that it slides easily down the neck of the flask. Air is forced through a glass tube which reaches to the bottom of the flask and inside the piece of bright copper at the rate of three bubbles per second. The air is dried and purified by passing through a train of three wash bottles containing respectively caustic soda solution (sp. gr. 1.355), 10-per-cent silver nitrate solution and pure, strong H_2SO_4, thence through a tell-tale bottle half filled with dry oil. The test is carried out at various temperatures from 60 to 150° C. for a period of 45 hours, is cooled to a temperature below 100° C. and diluted with petroleum spirit in the ratio of three volumes of spirit to one of oil, taking care to remove all the deposit from the flask in which the test was carried out. After standing 12 hours, the liquid is decanted through a fine-grain filter paper and washed with petroleum spirit. Pure benzine is then used to dissolve the sludge from the filter paper into a tared bottle from which the solvent is evaporated to constant weight, and the percentage in the original oil computed from this weight.

Modified Michie Test.—The following is one of the modifications of the Michie test:

One hundred cc. of oil is heated in a 150-cc. Erlenmeyer flask at 120° C. for 72 hours. The flask is partially submerged in an oil bath which is automatically regulated to within ± 1 or $1\frac{1}{2}°$ of 120° C. During this time pure oxygen is bubbled through the oil in a steady stream of fine bubbles. The lower end of the glass tube through which the oxygen is led in is drawn out into a capillary tube to make the oxygen bubbles small. When the test is to be made with copper, a piece of 60-mesh copper gauze 7 by $1\frac{1}{2}$ cm. is fastened around the end of the oxygen tube so that the oxygen, copper and oil come in intimate contact with each other. At the end of the 72 hours, while the oil is still hot, it is poured into a 100-cc. glass stoppered graduated cylinder and allowed to stand until cold. In case precipitation shows after the oil is cooled, it is allowed to stand until the precipitate has settled to the bottom. The approximate amount of precipitate is read on the graduated cylinder.

The above tests measure the oxidizing tendency of the oil in the belief that the unsaturated hydrocarbons are the ones which produce the sludge. It has been pointed out by one observer that the saturated paraffins may also be attacked when the conditions are suitable. To make sure that all of the bodies oxidizable under the conditions prevailing in a transformer are oxidized, an entirely different procedure has been suggested which uses formaldehyde in the presence of sulfuric acid, giving the compound formalite. The details of this test are as follows:

Formalite Deposit Test.—Dissolve 21.5 g. (26 cc.) of the oil in 40 cc. of normal benzine or petroleum ether in a 250-cc. flask. Add 24 cc. of concentrated H_2SO_4 without shaking. Cool the mixture with ice water or cold tap water and add 12 cc. of 40-per-cent formaldehyde, shaking the flask gently until no more heat is evolved. Allow the reaction mixture to stand 30 minutes at room temperature and then transfer it to a $\frac{1}{2}$-liter flask containing about 125 cc. of water. Neutralize the acid with NH_4OH in excess and catch the resulting precipitate on a Gooch crucible. Wash with petroleum ether or naphtha to remove the oil and then with water to thoroughly remove the $(NH_4)_2SO_4$. Dry at 100° C. (212° F.) to constant weight. The weight in grams shall be taken as representing the weight of the unsaturated hydrocarbons.

REPORT OF COMMITTEE D-10
ON
SHIPPING CONTAINERS.

At the meeting of Committee D-10 at Asbury Park last June the creation of a sub-committee on tight barrels was suggested and authorized. After some trouble in finding the necessary number of interested and qualified non-producers the sub-committee was formed as follows:

C. F. Meyer, *Chairman*,
Walker L. Wellford,
Edmund C. King,
G. E. Carleton,
William J. Pitt,
T. R. C. Wilson.

A Sub-Committee on Nomenclature and Definitions was also appointed as follows:

T. R. C. Wilson, *Chairman*,
W. D. Burr,
G. E. Carleton,
T. W. Ross,
Wirebounds Corporation,
Represented by G. C. Babcock.

There have been changes during the year in the representation of two corporate members. Four members have been added to the committee and one has resigned.

At a meeting which was held at Chicago on April 7, the sub-committee on wirebound boxes unanimously recommended the attached tentative general specifications for 4-one and similar type boxes. These specifications were developed by the 4-ones Box Machine Makers and the 4-ones Box Makers Association, both of which organizations are represented on the committee and have worked in cooperation with the committee. The committee voted to submit these specifications to letter ballot of its members with respect to publication by the Society as a tentative standard. Other sub-committees, although they have been more or less active, have not reported additional specifications for action of the committee.

The need for standards for the construction of crates of various types has been considered by the committee. In view of the fact that there is no accepted definition of crates as distinct from boxes it was deemed inadvisable at the present time to create a separate subcommittee to deal with this subject and Sub-Committees II and III have been authorized to include in their activities a study of crates and the drafting of specifications therefor, Sub-Committee II to deal with nailed crates and Sub-Committee III with wirebound crates.

Numerous organizations represented on Committee D-10 are conducting extensive tests and investigations looking to the improvement of shipping containers. Results of such investigations are to a large extent available to Committee D-10 and its sub-committees.

Results of a considerable amount of testing work on boxes for two sizes of canned foods are available to Sub-Committee I on Fiber and Corrugated Fiber Containers.

Members of Sub-Committee II on Nailed and Lock-Corner Containers are active in standardization, specification, and research work and have access to extensive tests of boxes and crates of the types with which they are concerned as well as tests of the strapping of boxes. This sub-committee hopes during the coming year to add to the present Tentative General Specifications for Wooden Boxes, Nailed and Lock-Corner Construction, rules for the strapping of wooden boxes and to define the allowable variation in the thicknesses of the parts of boxes when strapped. It is expected also that detailed specifications for wooden boxes for carrying boots and shoes, macaroni products and probably one or two other products will be brought out.

In addition to the above, the sub-committee on nailed and lock-corner containers expects to have up for consideration general specifications for wooden crates, nailed construction.

Members of Sub-Committee III on Wirebound Containers are active in the formulation of specifications and standards of construction for containers of this type. They have available results of extensive research work on construction of containers and on packing of various commodities. It is expected that this sub-committee will present next year detailed specifications for boxes for a considerable number of products. They will also have under consideration specifications for wirebound crates.

Sub-Committee IV on Nomenclature and Definitions has done some preliminary work which has brought out the need for standard definitions and the difficulty of defining some of the terms relating to shipping containers. It is hoped that it will be possible to draw up tentative definitions for such terms during the year.

Results of recent tests on Douglas fir barrels and tests made some years ago on oak barrels will be used by the new sub-committee on tight barrels in making specifications which they hope to present next year.

Committee D-10 recommends that the Society accept for publication as tentative the Tentative General Specifications for 4-One and Similar Type Boxes, as appended to this report.[1] The result of the letter ballot of the committee on this recommendation is as follows: Affirmative, 21; negative, 0; not voting, 10.

This report has been submitted to letter ballot of the committee which consists of 31 members, of whom 22 have voted affirmatively, none negatively, and 9 have refrained from voting.

Respectfully submitted on behalf of the committee,

J. A. NEWLIN,
Chairman.

T. R. C. WILSON,
Secretary.

EDITORIAL NOTE.

The proposed Tentative General Specifications for 4-One and Similar Type Boxes referred to in this report were accepted for publication as tentative and appear on pages 741–745.

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[1] See p. 741.—ED.

REPORT OF COMMITTEE D-11
ON
RUBBER PRODUCTS.

The committee has held three meetings during the year in addition to the one held during the 1920 annual meeting of the Society, which were well attended.

Committee D-11 now has before the Society seven standards and two tentative standards. These represent work over a number of years so that naturally there is a considerable amount of inconsistency between many of the standards and all departed more or less from the form and style which is now recommended. It was felt therefore that the first work of the committee could very well be the revision of six of the seven standards as to form and style. But in the course of this work, changes in substance were found desirable for one reason or another with the result that the committee has revised these six specifications in both form and substance and recommends that they be reduced to a tentative status. The one remaining standard, the Standard Methods for Testing Cotton Rubber-Lined Hose has been left undisturbed, but the two tentative standards now before the Society have also been revised. In addition, two new tentative standards have been prepared. The further details of the work of the committee during the year will be given under appropriate headings.

Fire Hose Specifications.—The Public Fire Department Fire Hose Specifications of the Society differed from those of the National Board of Fire Underwriters in a number of details, but none of the differences was great. The committee decided that any advantage to the Society due to having a separate standard was outweighed by the disadvantage of having two standards which were nearly alike. These specifications have therefore been revised to conform to the requirements of the N.B.F.U. Specifications.

In the case of the Private Fire Department Fire Hose Specifications, a similar action was taken. In addition, the standard size was changed from $2\frac{5}{8}$ to $2\frac{1}{2}$ in. which is one of the standard sizes for Public Fire Department fire hose. The majority of the committee believed that while the $2\frac{5}{8}$-in. hose will obviously deliver a given amount of water with less loss of head, the difference is not sufficient to outweigh the greater cost due to the size being an odd one. Making the size 2½ in. enables manufacturers to supply the same hose for both Private and Public Fire Department use, the latter simply having an additional jacket applied.

These two proposed revised specifications are appended hereto[1] and it is recommended that they be accepted for publication as tentative standards. The following tabulation shows a comparison of the more important items in the old and new specifications.

	Public Fire Department.		Private Fire Department.	
	Present Standard.	Proposed Standard.	Present Standard.	Proposed Standard.
Tests of rubber lining:				
Tensile strength, lb. per sq. in.	1600	1600	1600	1600
Elongation, in.	2 to 12	2 to 12	2 to 12	2 to 12
Set, per cent	20	25	20	25
Friction, weight used, lb.	13.5	12.0	13.5	12.0
Pressure tests, lb. per sq. in.:				
Proof test	400	400	300	300
Maximum pressure test	600	600[a]	500	500
"Kink" test	350	300[a]	300	250
Elongation under pressure, per cent	8	9	13	13
Twist per foot under pressure, deg	12	15	25	25
Warping under pressure, in.	..	20	20	20
Chemical properties, maximum per cent:[b]				
Total sulfur	3.0	4.0	3.0	4.0
Free sulfur	1.2	1.25	1.2	1.25
Acetone extract	2.0	4.0	2.0	4.0
Alcoholic potash	0.8	1.5	0.8	1.5
Chloroform extract	...	2.0	...	2.0

[a] 2½ in.; 250 lb. for 3 and 3½ in.

[b] In the present standard, the requirements are based on the rubber found by analysis and these figures are for 40 per cent of rubber in the compound. In the proposed standard the percentages are based on the weight of the compound.

Air Hose Specifications.—During and since the war the use of pneumatic tools to replace expensive manual labor has increased very rapidly and the standard practice in the use of air hose has changed very considerably. Therefore, even though one of our two air hose specifications was advanced to standard only last year, it seemed desirable to revise them both and to change the classification to conform to current practice. The distinction between terminal lengths next to the tools which are covered by our present specification entitled "Leader Hose" and the main line hose, which is covered by the present specification entitled "Air Line Hose" is no longer observed. The same type of hose, that is, with either braided or wrapped reinforcement, may be used throughout an entire system and as all sizes and kinds of tools are now employed, different sizes of "leaders" are necessary so that the limiting of our present leader hose specification to one size is no longer in accordance with practice.

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[1] See pp. 773–783.—Ed.

It is recommended that the two present standards: namely, the Standard Specifications for Leader Hose for Use with Pneumatic Tools and the Standard Specifications for Air Line Hose for Use with Pneumatic Tools be replaced with the two tentative specifications appended hereto for Wrapped Air Hose for Use with Pneumatic Tools and for Braided Air Hose for Use with Pneumatic Tools.[1] Both specifications cover a range of sizes from $\frac{3}{8}$ in. to $1\frac{1}{2}$ in. The quality requirements are substantially the same as in the present specifications, the following being the more important changes:

1. In hose of braided construction, the physical tests for the rubber have been lowered somewhat. For example, the tensile strength requirement is 800 and 700 lb. per sq. in. for the tube and cover respectively instead of 1000 and 800 lb. per sq. in. respectively as prescribed in the present "Leader Hose" specifications. It is believed that these lower values are ample for hose of the braided construction where the reinforcement yields less and takes more of the stress. Greater strength of the lining would be of no value as such nor would any greater life, which a higher strength rubber might have, be of any practical use, because air hose is worn out in service, disintegrated by oil, cut, etc. long before the limit of the life of the rubber lining itself is reached.
2. The hydrostatic test on each length of both wrapped or braided hose has been eliminated. It is understood that this requirement in the present specifications is not being followed on account of the expense involved, especially where the hose is armored, which is the usual practice. In that case the tests had to be made before the armor was applied, which necessitated an extra trip of the inspector to the factory.
3. The sample selected for the bursting pressure test has been reduced from a full length to 3 ft. It was believed that it was not wise to make this bursting test on a full length which would subsequently be put into service and, on the other hand, it would be uneconomical to throw away 50 ft. of hose. It is believed that the same purpose would be served by making the test on 3 ft. and increasing the required pressures somewhat.

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[1] See pp. 784–791.—ED.

Steam Hose.—The present Standard Specifications for Steam Hose (D 54 – 20)[1] closely agree with the M.C.B. Specifications. The M.C.B. specifications are now being revised, but the revision will not have been completed in time for this committee to consider the changes before the June meeting of the Society. Since this product is very largely used by the railroads and it is desirable that our specifications continue in close agreement with the M.C.B. Specifications, it is recommended that our specifications be reduced to a tentative status so that prompt revision can be made next year. It is obvious that when revision is in contemplation, it would be undesirable to have this standard go into the 1921 Triennial Book of Standards which will be published this year.

Rubber Belting.—Although these specifications were made standard only last year, several changes appear to be desirable to bring it in accord with current practice. It has also developed that certain sections in these specifications were found not to be entirely practicable. The more important changes may be summarized as follows:

1. Allowable stretch under load of 100 lb. per ply increased from 5 to 7 per cent. Rate of separation of jaws may be $1\frac{1}{2}$ to 4 in. per minute instead of about $\frac{1}{2}$ in. This slightly additional stretch is believed to be an improvement.

2. Ultimate strength required reduced from 285 lb. per ply to 260 lb. per ply. While of course belting has met the old requirement, the margin was very close and it was deemed advisable to increase the margin by this small amount.

3. The elimination of the requirement to submit sample pieces of cover compound and beading compound "guaranteed to truly represent the composition and degree of vulcanization of the belting delivered." This requirement was for the purpose of getting test specimens of the rubber used in the belting as it is not feasible to take specimens of these elements directly from the belting. It has been concluded by the committee, however, that this method of getting the desired information is not sufficiently reliable to be worth while. With the best of intentions on the part of the manufacturer, there can be no absolute certainty that the samples are exactly the same as the belting in all physical respects. It is believed, therefore, that this requirement can be dropped without making any material sacrifice.

It is recommended that the revised specifications as appended hereto[2] be accepted for publication as tentative.

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[1] A.S.T.M. Standards adopted in 1920.

[2] See p. 795.—ED.

Insulated Wire and Cables.—This standard has been materially improved. No extensive revision has been made but some new material has been added. It is be noted that the tolerance on area and methods of measurement are not in agreement with the Standard Specifications for Bare Concentric-Lay Copper Cable: Hard, Medium Hard or Soft (Serial Designation: B 8). However, Committee D-11 believes that its recommendation is more in accord with current practice. Committee B-1 has decided that any change in Specifications B 8 should be deferred until this matter has been considered by the American Engineering Standards Committee, which has the matter of unification of wire and cable specifications in hand at the present time, and in this decision Committee D-11 concurs. The more important changes are as follows:

1. *Thickness of Insulation.*—A table of recommended thicknesses of insulation for various working pressures has been added together with details of procedure for measuring the thickness, including the variation limits, rejection conditions, etc.
2. *Tape.*—A new sub-division covering tape where tape is employed has been added.
3. *Braid.*—A new sub-division covering braid has been added.

It is recommended that these revised specifications as appended hereto[1] be continued as a tentative standard.

Tape.—There is now before the Society Tentative Specifications for Adhesive Insulating Tape. These specifications have been improved as to form and arrangement, revised in some minor particulars and have been amplified to cover all of the widths which are in commercial use. Also, the title has been changed to more accurately describe the material covered. The revised specifications entitled Proposed Tentative Specifications for Commercial Adhesive Tape for Electrical Purposes are appended hereto[2] and it is recommended that they be continued as tentative for another year.

New specifications for rubber insulating tape have been prepared and are appended hereto under the title Proposed Tentative Specification for Rubber Insulating Tape.[3] It is recommended that these specifications be accepted for publication as a tentative standard.

Rubber Gloves.—There are appended hereto Proposed Tentative Specifications for Rubber Gloves for Electrical Workers.[4] The subcommittee which prepared them have kept in close touch with the Accident Prevention Committee of the National Electric Light Association, a committee which has taken much interest in this subject and which recommended a specification to the members of the N.E.L.A.

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[1] See p. 746.—ED. [2] See p. 799.—ED. [3] See p. 802.—ED. [4] See p. 805.—ED.

a few years ago. That specification was based on a rather thorough study of the subject made at that time with which some of the members of this committee were familiar. It is believed that the present proposed specifications, including as they do the changes which experience has shown to be desirable in the N.E.L.A. Specification, are the best all-around specifications yet presented to the industry. It is therefore recommended that they be accepted for publication as tentative.

The letter ballot vote of the committee on the revisions of the present tentative and standard specifications and on proposed new specifications is as follows:

	STATUS.	AFFIRMATIVE.	NEGATIVE.	NOT VOTING.
Tentative Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use.	Revision of present standard.	23	1	9
Tentative Specifications for Cotton Rubber-Lined Fire Hose for Public Fire Department Use.	Revision of present standard.	22	1	10
Tentative Specifications for Braided Air Hose for Use with Pneumatic Tools.	Revision of present standard.	23	2	8
Tentative Specifications for Wrapped Air Hose for Use with Pneumatic Tools.	Revision of present standard.	25	0	8
Tentative Specifications for Rubber Belting for Power Transmission.	Revision of present standard.	22	3	8
Tentative Specifications for Insulated Wire and Cable: 30 Per Cent Hevea Rubber.	Revision of present tentative standard.	21	0	12
Tentative Specifications for Commercial Adhesive Tape for Electrical Purposes.	Revision of present tentative standard.	21	1	11
Tentative Specifications for Rubber Gloves for Electrical Workers.	New.	22	0	11
Tentative Specifications for Rubber Insulating Tape	New.	22	1	10

The work of the committee now on hand or contemplated includes the following:

Pump Valves.—After several attempts on the part of the sub-committee dealing with this subject to get specifications which would be approved by the main committee, it has been reorganized and a new start is being made. The sub-committee is planning specifications for cold water pumps, for hot water pumps and for air pumps. It is expected that some of this material will be ready for presentation to the main committee at the June meeting.

Methods of Testing.—One of the standards of the Society which was prepared by this committee is entitled Standard Methods for Testing Cotton Rubber-Lined Hose. This standard needs some revision to bring it up to date but in doing so it is proposed to consider a plan of making the standard a more general one to include the methods for the general physical and chemical tests for all of the rubber products covered by the committee.

Cooperation with the Bureau of Standards.—The Bureau of Standards is planning to make an extensive investigation of some of the fundamental problems in connection with vulcanized rubber products and a sub-committee of Committee D-11 is, at its invitation, advising with the Bureau on the program for the work. Committee D-11 has recommended that the matter of an accelerated aging test be given first attention and it is hoped that favorable action will be taken on this recommendation.

Weather-Stripping.—The committee contemplates taking up the subject of specifications for weather-stripping for railroad cars.

This report has been submitted to letter ballot of the committee, which consists of 33 members, of whom 25 have voted affirmatively, one negatively, and 7 have refrained from voting.

Respectfully submitted on behalf of the committee,

F. M. FARMER,
Chairman.

C. B. MARTIN,
Secretary.

EDITORIAL NOTE.

The proposed revisions of the Standard Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use, for Cotton Rubber-Lined Fire Hose for Public Fire Department Use, for Leader Hose for use with Pneumatic Tools, for Air-Line Hose for Pneumatic Tools, for Rubber Belting for Power Transmission, and for Steam Hose were accepted for publication as new tentative standards and appear on pages 773–798. The standard specifications were accordingly withdrawn.

The proposed revisions of the Tentative Specifications for Insulated Wire and Cable: 30 per cent Hevea Rubber and of the Tentative Specifications for Adhesive Insulating Tape referred to in this report were accepted. The specifications as thus revised appear on pages 746–772 and 799–801.

The proposed Tentative Specifications for Rubber Gloves for Electrical Workers and the proposed Tentative Specifications for Rubber Insulating Tape were accepted for publication as tentative and appear on pages 802–810.

MINORITY REPORT

REGARDING REVISION OF PRESENT COTTON RUBBER-LINED FIRE HOSE SPECIFICATIONS.

Committee D-11 is recommending for adoption a radical revision in the present Specifications for Cotton Rubber-Lined Fire Hose for Private Fire Department Use, the most important change being a reduction in diameter from $2\frac{5}{8}$ to $2\frac{1}{2}$ in. This apparently slight difference in diameter no doubt seems like a small matter to those who have not given the subject careful study, but when certain hydraulic facts are taken into consideration this change in diameter assumes a different aspect.

The origin of the $2\frac{5}{8}$-in. diameter dates back about thirty years when Mr. John R. Freeman, the well-known hydraulic engineer, conducted friction loss tests on various sizes of cotton rubber-lined hose. He found that the friction loss or drop in pressure with varying quantities of water flowing in 2, $2\frac{1}{2}$ and 3-in. hose followed the well-known hydraulic formula that for the same quantity of water flowing in long pipes the friction loss is inversely proportional to the fifth power of the diameter. Having thus established the applicability of this law for cotton rubber-lined hose, he computed the difference in friction loss between $2\frac{1}{2}$ and $2\frac{5}{8}$-in. hose and found this figure to be between 3 and 4 lb. per 100 ft. with 250 gallons of water flowing. The results of these tests have been published in full in the transactions of the American Society of Civil Engineers, Volume XXI, November, 1889.

Appreciating that it would be possible to change the diameter of fire hose to $2\frac{5}{8}$-in. without interfering with the couplings and hydrant connections then in use, and realizing the importance of decreased friction loss with the larger hose, Mr. Freeman urged upon the hose manufacturers the desirability of making all fire hose, at least for private department use, $2\frac{5}{8}$ in. in diameter. This was readily agreed to and from that time until recently the standard diameter for this type of hose has been $2\frac{5}{8}$ in.

Owing to the fact that the matter was never properly presented to city fire departments—probably due to lack of any organization in a position to sponsor the subject—the standard diameter for this class of hose continued to be $2\frac{1}{2}$ in. The use of the smaller diameter for public departments has never been considered of as great importance as in the case of private department hose, since the city departments usually have pumping equipment capable of furnishing high pressures, and this generally suffices to offset the increased friction loss. Nevertheless, there are situations where hose with a lower friction loss would appreciably increase the efficiency of the fire departments.

In the last few years there has been a movement on foot, originating from certain interests, to eliminate the $2\frac{5}{8}$-in. size for private department use and to make the standard $2\frac{1}{2}$ in. in diameter, the advocates of this change basing their contention on the desirability of standardizing manufactured products and eliminating odd sizes.

In view of this movement, the Factory Mutual Laboratories with which the writer is connected, conducted in the fall of 1920 a careful series of tests to obtain more recent data on friction loss in hose as manufactured today, and also to make tests on the $2\frac{5}{8}$-in. hose itself rather than leave the matter to computation. These tests, based on a number of lengths of hose from different manufacturers, showed that the average friction loss in $2\frac{1}{2}$-in. hose is about 3.25 lb. greater per 100 ft. than in $2\frac{5}{8}$-in. hose, equivalent to an increase of over 25 per cent, thus confirming fully the figures obtained by Mr. Freeman.

The average length of hose lines at fires where private department equipment is used is at least 300 feet, and in some cases is greater. It is evident, therefore, that the decrease in pressure with the $2\frac{1}{2}$-in. hose will be about 10 lb. more than with $2\frac{5}{8}$-in. hose, and this may mean the difference between saving a property or losing it.

The tendency of modern fire protection engineering has been to eliminate friction loss in fire protective devices (hydrants, pipe fittings, check valves, etc.) as far as possible. It is with this thought in mind that the engineer, in laying out a fire protective system may specify 8-in. pipe instead of 6-in., or 10-in. instead of 8-in., and yet if this revision is adopted this Society will be in the position of taking a backward step which will nullify much that has been accomplished in improving fire protective equipments throughout the country.

The desirability of standardization is not overlooked, but it would seem like good engineering and wise judgment to standardize on that diameter which the best engineering practice would indicate. In other words, if it is so desirable to standardize on one size, why not make all hose, both private department and fire department, of the $2\frac{5}{8}$-in. diameter? In any event, if this cannot be accomplished the elimination of the $2\frac{5}{8}$-in. size for fire department use represents too great a sacrifice for the sake of standardization.

Respectfully submitted,
ED. A. BARRIER.

DISCUSSION.

Mr. Farmer. Mr. F. M. Farmer (*Chairman of Committee D-11*).—As the Secretary has indicated in presenting Mr. Barrier's Minority Report, the report was considered by Committee D-11 at its meeting last night. I may say in the first place, that these points were all brought up when this change was first considered by the committee, and as Mr. Barrier was chairman of the Sub-Committee on Cold Water Hose he naturally had ample opportunity to present his case. The decision of the committee is very well indicated by the vote on the prepared specifications, namely 22 to 1.

Now as to the two points which Mr. Barrier emphasizes particularly in his minority report. First, he states that the friction in reducing from a diameter of $2\frac{5}{8}$ to $2\frac{1}{2}$ in. is increased 3.25 lb. per 100 ft. of hose for 250 gallons per minute of water flowing; and, second, that our recommended change is not in accordance with the trend of current practice, namely, to reduce the friction in pipe fittings, hydrants, etc., and is toward larger mains.

The essential reasons for the action on the part of the committees recommending these changes in spite of the objections raised by Mr. Barrier, are as follows: First, in reference to the increased friction, Mr. Barrier says that this amounts to 3.25 lb. An extensive investigation, made by the National Board of Fire Underwriters, on a much wider range of hose of different makes than in the investigation referred to by Mr. Barrier showed about 2.5 lb. However, the exact amount is really unimportant. The main question is, what is the effect of this reduction on the effectiveness of the hose in extinguishing fires? The committee viewed the problem about in this way: Assuming a hydrant pressure of about 60 lb., the nozzle pressure with a hundred feet of $2\frac{5}{8}$-in. hose, and a flow of 250 gal. per minute would be about 45 lb. Taking Mr. Barrier's figure of 3.25 lb. friction drop, the nozzle pressure with $2\frac{1}{2}$-in. hose would be 41.75 lb. Now the velocity of discharge and hence the volume of water delivered is in proportion to the square root of these pressures; consequently the net effect would be only something like $3\frac{1}{2}$ per cent. This is about the amount of the effect which the National Board of Fire Underwriters found in their investigation. One of the large manufacturers of hose checked up this matter in a rough but rather clear way by taking two lengths of

Mr. Farmer. hose, one $2\frac{1}{2}$ in. and the other $2\frac{5}{8}$ in. in diameter, both being otherwise exactly alike, that is fitted with the same fittings and nozzles (standard $1\frac{1}{8}$-in. nozzles), and connected them to one hydrant, where the pressure was of the usual order, about 50 lb. It could not be seen by observation that there was any appreciable difference in the effectiveness of the streams. That was not a laboratory test, of course, but it is a fairly conclusive one.

Incidentally, Mr. Barrier mentions the use of long lengths in connection with this friction matter, and the view of the committee is that long lengths are not generally used in private fire department protection, not nearly as much as in public fire department work; in other words, the hydrants are supposed to be sufficiently close together to eliminate the use of long lengths. The inspection bureaus of the insurance organizations aim to see that this is the case.

As to the trend of practice, it is quite true, of course, that it is desirable to reduce the friction in the whole system, but those changes referred to by Mr. Barrier can be made without introducing any element of cost. For instance, the friction can be reduced in all the fittings and no disadvantage is involved, as a rule, not even any appreciably greater cost. But when it comes to the hose, there are other disadvantages in the larger size beside greater cost and two standards. One is the matter of handling hose. When the hose is above $2\frac{1}{2}$ in. in diameter, with a pressure of the order of 50 lb., which is only moderate, it becomes about all one man can handle, especially the average man available in an emergency in a private plant to handle hose who is not an experienced man. Consequently there is a limit in that direction to which we can go, and the committee felt that $2\frac{1}{2}$ in. was about that limit. Now, in view of the fact that the disadvantages are of a small order, the committee felt that the great advantage of standardization, a very obvious advantage which we do not need to discuss and which is in accord with the trend of the times, far outweighed those disadvantages, and it still recommends that its action be approved by this meeting.

[There was no further discussion and the meeting adopted the motion to accept the proposed revised Specifications for Cotton Rubber-Lined Fire Hose for Private Department Use for publication as tentative.[1]—ED.]

Mr. Stratton. MR. S. W. STRATTON, U. S. BUREAU OF STANDARDS (*written communication*).—On reading over the preprint of the report of Committee D-11 on Rubber Products, we find two or three matters which we can not accept without a protest. These all relate to the method of analysis in Appendix II of the Tentative Specifications for Insulated Wire and Cable.[1] **Mr. Stratton.**

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[1] See p. 773.

Under "Sample," Section 7, there should be some word of caution about grinding slowly enough not to heat the sample. Some laboratories may not have one, but if they do, they should use a rubber mill for grinding the sample.

In Fig. 3, the flask ought not to be labeled "Bohemian Glass," but rather "Resistance Glass." American glass is as good as Bohemian.

Under "Checks," Section 30, there is given a table showing how closely duplicate determinations of the different constituents should check. While it may be possible with very careful work to obtain such close checks when making duplicate analyses of a given sample simultaneously, such a degree of concordance will be accidental with some of the determinations. For instance, in determining the acetone extract it will be necessary to weigh with an accuracy of 2 mg. Even if everything possible is extracted and saved, there are chances of error. In spite of the long period of drying, minute drops of moisture may remain trapped in the resinous material. This material is spread on the glass differently in the two flasks, so that in one case the drying may be more rapid, and at the same time volatilization of part of the sulfur and oxidation of the organic matter can take place more readily. Finally, our experience in testing glassware, when weighings are made against a tare of the same size and shape, has shown us that it is not possible to obtain checks as close as 2 mg. with certainty.

If it is so difficult to check so closely when making duplicate analyses of a given sample, how much harder will it be if two parts of the same length of insulated wire are analyzed in different laboratories.

We are convinced that the limits set for the different constituents should be higher.

Finally, we urge that a serious attempt be made to devise some less difficult and cumbersome method for the analysis of 30-per-cent insulation. Only a very experienced analyst can obtain close checks by the present method. This Bureau has no other method and is not working on one, but would willingly cooperate with Committee D-11 in anything it undertakes along that line.

Mr. Farmer. MR. FARMER.—The Bureau's communication was considered at the meeting of the committee last night, and the committee's decision was about as follows: First, it should be borne in mind that the

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[1] See p. 746.—ED.

Mr. Farmer. standard procedure which appears in Appendix II is not the work of Committee D-11, but is the work of a much more representative and authoritative body. Those rubber chemists who are present will bear me out, I think, when I say that that work which has been standing as an authoritative procedure for six or seven years, was the result of a very great deal of effort in getting all of the rubber chemists in the country together and getting a final agreement on a subject which had been a bone of contention for years, namely, a standard procedure for the analysis of rubber insulation in controversial cases. Before that time it was impossible to get two different laboratories to agree, simply because they did not use the same method, and that committee finally got out a specification which was generally agreed to as a referee procedure, and it is only intended primarily to be used for that purpose. It being the case that it is the work of such a representative body and the result of a great deal of investigation, this committee does not feel that it is within its province to recommend any change. Furthermore, the committee does not feel that, even though it did consider this matter within its province, this is the time to undertake such work, because the whole subject of which this is a part, namely, the standardization of specifications for wire and cable, is now before the American Engineering Standards Committee. It has started the work of unification of the great number of specifications for wire and cable now in use in this country under the head of an American standard for wire and cable of all kinds. Obviously the chemical procedure for the analysis of rubber insulation will be a part of the work of that committee and will receive due attention. The committee therefore believes that it should not take any action at this time on the points raised by the Bureau of Standards.

[There was no further discussion and the meeting adopted the motion to accept the proposed revised Specifications for Insulated Wire and Cable: 30-per-cent Hevea Rubber for publication as tentative.[1]

Subsequently, the minor modification in Section 7, suggested by the Bureau of Standards, was made.—ED.]

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[1] See p. 746.

REPORT OF COMMITTEE D-13
ON
TEXTILE MATERIALS.

Committee D-13 on Textile Materials has held two meetings during the past year. The first meeting was held at the Lowell Textile School, Lowell, Mass., on October 22, 1920, and the second at the Engineering Societies Building, New York, March 11, 1921.

Two tentative standards have been prepared this year:

Definitions of Terms Relating to Mechanical Fabric.

Specifications for Imperfections and Tolerances for 60-in. 17$\frac{1}{4}$-oz. Square-Woven Tire Builder Fabric.

The Definitions of Terms Relating to Mechanical Fabric is offered as a plan for convenient reference to Mechanical Ducks in an effort to avoid confusion which now exists. At present, reference to Mechanical Ducks in terms of weight may mean weight per linear yard based on various widths used arbitrarily by the industries responsible for the development of these fabrics. The principal object of the proposed nomenclature is to standardize weight specifications to a square yard basis. For the convenience of those who find it necessary to convert from the present linear yard weight basis to the proposed square yard weight basis, a conversion table is attached to the Proposed Tentative Definitions of Terms Relating to Mechanical Fabric.

The Proposed Tentative Specifications for Imperfections and Tolerances for 60-in. 17$\frac{1}{4}$-oz. Square-Woven Tire Builder Fabric consists of a list of tolerances to be used in connection with specifications submitted by consumers to manufacturers, and also includes a list of imperfections intended to serve as a glossary so manufacturers and consumers may be brought to a closer understanding as to the meaning of references to various imperfections in tire fabrics. While it is customary for tire fabric to be manufactured to specifications, these specifications vary considerably, according to the requirements of tire manufacturers based on their methods of operation, and an attempt to draw up definite specifications for fabrics is not considered to be desirable at this time. There has been some misunderstanding, however, between manufacturers and consumers as to allowable variations from specifications, and it is to provide basis for adjusting such conditions that these tolerances are proposed. These tolerances and imperfections have been developed by Sub-Committee VI on Imperfections and Tolerances, and are based on answers to a questionnaire submitted to tire fabric and tire manufacturing industries.

Sub-Committee VIII on Publicity with the approval of the Executive Committee of the Society was authorized to give more publicity to the Standard General Methods for Testing Cotton Fabrics than has heretofore been given, in an effort to extend the use of these standards in the textile industry.

Committee D-13 through its sub-committees is engaged in the development of standards on the following subject:

Test methods and measurements for fibers.
Test methods and specifications for yarns.
Specifications for fabrics.
Specifications for fabric testing machines.

The two proposed standards are appended hereto[1] and it is recommended that they be accepted for publication as tentative. They have been submitted to letter ballot of the committee, consisting of forty-four members, with the following results:

	AFFIRMATIVE.	NEGATIVE.	NOT VOTING.
Definitions of Terms Relating to Mechanical Fabric ..	31	5	8
Imperfections and Tolerances for 60-in. 17¼-oz. Square-woven Tire Builder Fabric........................	26	9	9

This report has been submitted to letter ballot of the committee which consists of 44 members, of whom 27 have voted affirmatively, 3 negatively, and 14 have refrained from voting.

Respectfully submitted on behalf of the committee,

A. E. JURY,
Chairman.

G. W. SKIRM,
Secretary.

EDITORIAL NOTE.

The proposed Tentative Specifications for Imperfections and Tolerances for 60-in., 17¼-oz. Square-Woven Tire Builder Fabric and the proposed Tentative Definitions of Terms Relating to Mechanical Fabric referred to in this report were accepted for publication as tentative and appear on pages 811–816.

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[1] See pp. 811–816.—ED.

REPORT OF COMMITTEE D-14
ON
SCREEN WIRE CLOTH.

Since the last annual meeting of the Society the Executive Committee has authorized the formation of Committee D-14 on Screen Wire Cloth and has appointed the various members of this committee. The committee was formally organized on October 20, 1920, at which time the officers and sub-committee chairmen were elected and the general policy and future program were formulated.

For the present the committee will confine its work to the standardization and testing of non-ferrous insect screen cloth, but will broaden its activities at a later date or as the necessity arises.

There are two classes of producers represented on the committee: first, those manufacturers producing wire suitable for weaving into screen cloth, and second, those manufacturing the woven wire screen cloth. The non-producers include manufacturers using the wire screen cloth in constructing insect screens and representatives of various Government departments. These facts have been duly considered in the formation of the sub-committees.

Sub-Committee I on Wire for Weaving is at present drawing up specifications for the wire of those non-ferrous metals and alloys which are ordinarily used for insect screens.

Sub-Committee II on Manufacture of Wire Screen Cloth is engaged in preparing specifications for the finished woven wire screen cloth.

Sub-Committee III on Nomenclature and Definitions was organized in an endeavor to straighten out some of the controversies which have previously existed in the nomenclature of the alloys commonly used for screen wire cloth.

Sub-Committee IV on Testing of Screen Wire Cloth will conduct tests on the durability of the various grades of insect screen cloth and during the coming year will set ou texposure test panels at different parts of the country under various climatic conditions.

The report this year is necessarily one of progress only but it is hoped that by next year the committee will have definite recommendations and standards to present to the Society.

This report has been submitted to letter ballot of the committee, which consists of 14 members, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. W. Woodward,
Chairman.

W. H. Bassett,
Secretary.

REPORT OF COMMITTEE E-1

ON

METHODS OF TESTING.

As an introduction to its annual report, Committee E-1 believes it is desirable to review briefly the history of the preparation of methods of testing in the Society. When the committee was first organized in 1904, the problem immediately confronting it was the development of standard methods of testing metals, especially iron and steel. After six years' study the committee submitted in 1910 methods for tension, compression and metallographic tests of metals, and subsequently, methods for transverse and Brinell hardness tests of metals; all of which are now published under the broad title "Standard Methods for Testing (E 1 - 18)." In the meantime the field of the Society was rapidly expanded to include, besides steel and iron, the non-ferrous metals, cement, lime, gypsum and clay products, preservative coatings, petroleum products, road materials, timber, rubber and textile products, and so on. As new committees were organized to study these materials, it was a matter more or less of normal growth that they should assume responsibility for the study and development of methods of testing those materials. As a result, the work of the Society in the promulgation of methods of testing has developed in this way: that methods for testing metals have remained in the charge of Committee E-1, whereas methods for testing the wide variety of non-metals have been in the charge of the respective standing committees—those in the groups of the Society's committee organization designated "C—Cement, Lime, Gypsum and Clay Products" and "D—Miscellaneous Materials." Even in so far as metals are concerned, it was found desirable that magnetic, metallographic and chemical methods should be developed by separate committees, leaving perhaps only the field of mechanical testing of metals to Committee E-1.

In other words, the very evident trend of Society growth along this line has been to concentrate in the respective standing committees responsibility for the preparation of all standards for materials within their field, including methods as well as specifications. And when one looks over the tremendously broad field now covered by the Society, it may readily be appreciated that any other development would have been impracticable, if not wholly impossible of accomplishment.

Within the last year or two, the methods of testing submitted by the various standing committees have rapidly multiplied. It frequently happens that a method prepared by one committee for testing a certain property of the material it is studying, will be nearly the same as another method prepared by some other committee for determining the same property in another material. The two committees may have approached the matter from slightly different viewpoints and devised slightly different methods, although it may be evident that the two methods could readily be harmonized and the resulting method still be entirely satisfactory for testing both of the materials. As illustrative of properties of materials that are of vital interest to a number of our committees there might be mentioned plasticity, consistency and workability, which are qualities of various cementitious materials that are receiving much consideration at this time; specific gravity, viscosity, flash point, distillation and other related properties of, for example, petroleum and tar products that are used for a wide variety of purposes and hence are of interest to a number of committees; methods of temperature measurements are of vital interest to many committees; the unification of sieves for testing purposes is an important matter; and there might be cited many similar instances.

Endeavors have been made at times to bring about uniformity in the action of two committees by forming temporary joint committees; but instances have multiplied so rapidly that it has seemed desirable to establish some permanent means of bringing about this desired uniformity, and of instituting cooperation between standing committees in these matters according to some definite, coordinated procedure in which each committee of the Society has its place and responsibility. Moreover the time has seemed opportune, not only to provide means for such coordination, but to create a single representative committee to which can be assigned the study and development of testing of materials in its broadest aspects, so as to advance most effectively that important part of the objects for which the Society is organized.

Accordingly, the Executive Committee announced a year ago that Committee E-1 would be reorganized to consist of seven members selected by the Executive Committee with special consideration of their interest, experience and ability in methods of testing, and not over two representatives from each standing committee dealing with technical matters. At the meeting for reorganization on this basis held November, 1920, and at a later meeting held February, 1921, there was a comprehensive discussion of matters relating to organization and procedure. While certain details are still under consideration and are expected to be decided during the annual meeting, a form of organization and procedure has been developed along the following general lines: The seven members appointed by the Executive Committee, who will be designated "Members-at-large," have been constituted as an advisory committee, which is charged by the committee with general direction of the committee's activities, including the appointment of the necessary sub-committees to carry on its work. The members appointed by the standing committees are designated "Representative Members." A method of test or group of methods referred to the committee by one or more standing committees for consideration will be reviewed by a sub-committee which must consist of at least one representative member of Committee E-1 from each standing committee interested in the method or group of methods, under the chairmanship of a member of the advisory committee. The interests of each standing committee in the consideration of the method are fully protected by the requirement that any standing committee, upon its request, shall be allowed to designate a representative member to serve on any sub-committee of Committee E-1. Thus, the discussion of the details of any method of test, particularly to the end that possible divergent views of several committees may be harmonized, is placed in the hands of the representatives of the committees interested, who are either personally familiar with the test methods under consideration, or who may bring into the sub-committee for advice especially qualified persons from their respective committees. The recommendations of these sub-committees are received and considered by the whole committee and voted upon by letter ballot in accordance with the general Society Regulations.

Definite functions have been delegated to the committee by the Executive Committee, as follows:

> (*a*) To aid and advise the standing committees in the preparation of standard methods and instruments of testing; in the correlation of similar methods in different committees; and in instituting cooperation between standing committees in matters relating to methods and instruments of testing by the creation of sub-committees of Committee E-1 or otherwise, especially on matters of common interest to a number of standing committees;
>
> (*b*) To initiate, conduct and report research upon such engineering constants, methods and instruments for testing and fundamental problems of interest to the Society, as do not come within the functions of any other standing committee;
>
> (*c*) To encourage, secure and promote, with the approval of the Executive Committee, cooperation in methods and instruments of testing between standing committees of this Society and the committees of other societies and associations;

(*d*) To standardize the nomenclature and definitions used in or relating to testing methods or instruments, in cooperation with the standing Committee on Nomenclature and Definitions; and

(*e*) To perform such other functions as may advance, improve, standardize and unify the science of materials testing.

It is furthermore the duty of the committee to review all methods of testing prior to their reference to the Society for adoption as standard. In this connection it should be clearly noted, however, that the responsibility for the preparation of methods and instruments of testing remains vested in the standing committees, and Commitee E-1 will not, nor can it, take from any standing committee the inherent responsibility that rests with it for the preparation of methods of test in the field assigned to it. Briefly stated, one of the major functions of Committee E-1 is, in cooperation with the committees themselves, to devise a procedure by which the several committees concerned with materials to which a given method of test may be applicable will be brought together so that they can function efficiently and with minimum duplication of effort in the formulation of methods of test. Undoubtedly some testing problems will be of such broad application that study of them can be most efficiently carried out through Committee E-1 itself with the active cooperation of the standing committees concerned. Such an instance is the work the committee is now doing in the revision of the Standard Methods of Testing Metals, to which reference is made later.

In all there have been held two meetings of the committee and two of its advisory committee, and each will meet again during the annual meeting. While much time has necessarily been devoted to matters of organization, considerable progress has been made in the consideration of the technical problems before the committee.

Revision of Standard Methods of Testing (*E 1 – 18*).—The Standard Methods of Testing (E 1 – 18), originally prepared by Committee E-1 in 1910 and including methods for tension, compression, transverse, Brinell hardness and metallographic tests of metals, have been previously referred to. One of the most important problems before the committee is the revision of these methods so that they will be thoroughly up to date both as to substance and form. Although the title of the methods does not indicate the fact, they deal exclusively with tests of metals and with the calibration of testing apparatus therefor. In view of the fact that the formulation of general methods of test applicable to non-metals, in itself a task of great magnitude, is already engaging the attention of many of our standing committees, the committee has decided to limit the Standard Methods of Testing (E 1 - 18) to metals. Moreover, at the request of the committee, Committee E-4 on Metallography has prepared a complete revision of that portion of the general methods relating to metallographic tests, which will be recommended by Committee E-4 in its annual report for adoption as a separate tentative standard.

Accordingly, Committee E-1 recommends to the Society that that portion of the Standard Methods of Testing (E 1 - 18) devoted to Metallographic Tests of Metals be withdrawn, provided the tentative methods proposed by Committee E-4 are accepted by the Society, and that the title of the methods be changed to read: "Standard Methods of Mechanical Testing of Metallic Materials."

The consideration of the revision of the remaining sections of the Standard Methods of Testing and their extension to include other tests than those indicated has been placed in the hands of a sub-committee consisting of the representative members of Committee E-1 from those committees dealing with metals, under the chairmanship of a member of the advisory committee, Mr. H. F. Moore. This sub-committee, which has already made considerable progress in its work, will keep in direct touch with each of these standing committees, to which it will refer for study the details of test methods of particular interest to them and upon which they are particularly qualified to work. The sub-committee will center its attention on methods of mechanical testing, leaving methods of chemical testing and metallographic testing in the hands of committees now at work on such methods. Additional sections dealing with torsion, shear, impact and fatigue tests are under consideration and it is expected within a year to present a report of substantial progress and possibly tentative revisions of the methods themselves.

Form of Methods of Test.—One of the first things that the committee found upon reviewing the various methods of test was in some cases lack of uniformity in the form and arrangement of test methods and there seemed to be here an opportunity for the committee to work out a desirable form of writing a test method. The Regulations Governing the Form but not the Substance of Standards, as originally drafted, were designed for application to specifications as distinguished from methods. The committee has accordingly prepared a suggested outline of the form in which a method of test should preferably be arranged, and will propose it for consideration during the coming year by Committee E-5 on Standing Committees, which is responsible for these general Regulations Governing the Form of Standards.

Index of Methods of Test.—There is being prepared in the office of the Secretary-Treasurer for the use of the committee a comprehensive index of methods of test that have so far been published by the Society. This work has been undertaken for the purpose of acquiring a complete oversight of the work of the Society in the preparation of methods. The index, which is now completed in card form in so far as standards and tentative standards adopted up to 1920 are concerned, is so arranged as to make it possible for the committee (1) to see which methods of test issued by the Society are closely related to others, thus facilitating comparison of tests of a similar nature prepared by different committees; and (2) to determine in the case of new tests which are submitted to the committee for consideration whether there are any tests already adopted by the Society closely related to the proposed test It is believed that the index when completely developed will be indispensable to Committee E-1 in its work of reviewing methods of test that are submitted to it. The magnitude of this work will be appreciated when it is stated that there are nearly fifty methods of physical testing adopted by the Society, not including numerous methods embodied directly in specifications, nor new methods that will be proposed this year.

Impact Testing.—The committee has organized a sub-committee to consider how the important subject of impact testing may be developed in the best manner by the committee. The sub-committee at present is reviewing considerable data submitted to the Society by the British Engineering Standards Association, as well as work that has been done by the Society on this subject and in this country in general. The committee believes that a proper study of methods of impact testing is an important matter and has under consideration the possible value of a general symposium on the subject at an annual meeting of the Society.

Other Matters under Consideration.—Some other matters that are now receiving the consideration of the committee are as follows:

The unification of the several distillation tests that have been proposed by various committees of the Society has been referred to a sub-committee consisting of the representative members of these committees on Committee E-1, under the chairmanship of a member of the advisory committee, Mr. A. W. Dow.

The best method of developing a proper study of the broad subject of temperature measurements, including thermometry and pyrometry is under consideration.

The consideration of certain tests of lime proposed by Committee C-7 on Lime will be undertaken and the work will be broadened to consider these and kindred tests in relation to other cementitious materials. Such tests, for example, as those for fineness, tensile strength, plasticity, consistency, etc., are included.

The committee has recognized the need of concerted study in the Society of the subject of standard screen sieves for testing purposes, to the end that wherever possible the unifying of the several scales of screens and sieves be accomplished; and this subject will be studied during the coming year by a representative sub-committee.

A general matter of considerable interest has been discussed in the committee and referred to a sub-committee for further study and development. It will be recognized that broadly speaking there are two purposes for which tests of materials are made: (1) To determine whether a given material or product conforms to specified requirements, in which case such tests may be designated "Control Tests;" and (2) to determine whether a material or product is entirely suitable for the purpose intended, to which form of test the name "Suitability Tests" might be given. The committee believes that it will be desirable as its work proceeds to emphasize the latter aspect of the testing of materials and to bring to the attention of the committees the importance not only of developing standard methods of control testing but of devising means by which the inherent properties of material may be studied to determine the suitability of the material for a given service.

Subjects Referred to Other Standing Committees for Consideration.—Mention has already been made of the request of the committee to Committee E-4 that it take over the development of metallographic tests of metals. The committee has also requested Committees A-6 on Magnetic Properties and A-8 on Magnetic Analysis to undertake the development of magnetic tests of metals and the correlation of magnetic with mechanical properties, which is directly in line with the work assigned to these two committees. The committee has called to the attention of Committee D-7 on Timber the importance of developing general methods of testing timber that may be published in a form analogous to the methods of testing metals. This suggestion has been favorably acted upon by Committee D-7 and the committee is actively at work on this subject.

During the year the committee was advised by Committee D-2 on Petroleum Products and Lubricants that it had under consideration proposed methods of test for flash point of volatile petroleum oils and for distillation of petroleum products. At the suggestion of the committee, these tests were developed in cooperation with other standing committees of the Society interested in them. With respect to the test for flash point, which has already been adopted as standard for volatile paint thinners, the committee understands that in its essentials it is already well established in the petroleum and related industries, and the committee has accordingly voted that it would interpose no objection to its presentation for adoption as standard provided it was approved by the two standing committees concerned, namely, Committees D-1 and D-2. The reports of these committees will refer to the matter in detail. With respect to the method of test for distillation, it is understood that this is offered only as tentative so that the committee will have an opportunity of reviewing it in connection with its study of distillation tests in general.

Problems for Future Consideration.—From what has been said it will be appreciated that the work before Commitee E-1 is of wide scope. The committee must review all methods of test that are now tentative particularly with a view of reconciling inconsistencies and, where they exist, conflicting requirements in similar methods offered by the several committees. It must lend its every effort to the development of a procedure that will facilitate the preparation of test methods, and reduce to a minimum the duplication of effort in the various committees. As time permits it must make a comprehensive study of the methods of test now adopted as standard to the end that any inconsistencies and conflicting requirements may be called to the attention of the proper standing committees and arrangements made for their reconciliation. The importance of this work, not only from the viewpoint of the Society's activities but from that of every industry concerned, will be self-evident. Obviously this work can be done only with the hearty support and cooperation of each standing committee of the Society, and Committee E-1 earnestly solicits that cooperation and support.

This report has been submitted to letter ballot of the committee, which consists of 41 members, of whom 39 have voted affirmatively, none negatively, and 2 have refrained from voting.

Respectfully submitted on behalf of the committee,

J. A. CAPP,
Chairman.

C. L. WARWICK,
Ex-officio Secretary.

REPORT OF COMMITTEE E-4
ON
METALLOGRAPHY.

Committee E-4 has held two meetings during the year and organized the following sub-committees:

I, on Selection and Preparation of Samples;
II, on Nomenclature and Definitions;
III, on Thermal Analysis;
IV, on Photography.

Mr. G. F. Comstock was elected secretary.

The committee accepted the invitation of Committee E-1 on Methods of Testing to become responsible for Standard Methods for Metallographic Tests of Metals.

The committee has prepared and offers for acceptance Tentative Methods of Metallographic Testing of Iron and Steel. These methods are intended to replace the corresponding methods now appearing in Sub-division V of the Standard Methods of Testing (E 1 - 18). It has also prepared and offers for acceptance Tentative Definitions of Terms Relating to Metallography to be used with Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys (E 2 - 20).[1]

Methods for Metallographic Testing of Non-Ferrous Alloys will be taken up with the idea of submitting tentative standards at the next annual meeting.

This report has been submitted to letter ballot of the committee which consists of 35 members, of whom 31 have voted affirmatively, none negatively, and 4 have refrained from voting.

Respectfully submitted on behalf of the committee,

W. H. Bassett,
Chairman.

G. F. Comstock,
Secretary.

Editorial Note.

The proposed Tentative Methods of Metallographic Testing of Iron and Steel and the proposed Tentative Definition of Terms Relating to Metallography referred to in this report were accepted for publication as tentative and appear on pages 817–831.

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[1] A.S.T.M. Standards Adopted in 1920.

REPORT OF COMMITTEE E-6
ON
PAPERS AND PUBLICATIONS.

Since the last annual meeting, Committee E-6 on Papers and Publications has held two meetings, one in December and one in March. In addition to its usual function of arranging the program of the annual meeting, it has acted in an advisory capacity to the Executive Committee in the consideration of several matters relating to publication policy.

The committee was advised by the Executive Committee that it would be necessary to observe every possible economy in issuing the 1921 publications and was requested to recommend to the Executive Committee ways in which this economy could most effectively be secured. The committee felt that, generally speaking, our committee reports are presented in as concise and direct form as possible and that to reduce the space in the Proceedings devoted to reports and tentative standards would mean a direct curtailment of committee work, which is not consistent with the normal and healthy growth of our activities. With respect to the technical papers, it was felt that there was some possibility of reducing their volume without detracting in any serious measure from their value. The committee also considered the possibility of saving space by increasing the amount of printed matter placed on a page. After investigation it was determined to change the size of type page from 4 by $6\frac{1}{2}$ in. to $4\frac{1}{3}$ by 7 in. This will result in a substantial saving of space, still leaving sufficient margin on the standard 6 by 9-in. page to retain good appearance and to permit the use of bold face marginal notes in connection with the publication of standards and tentative standards. On the other hand, the new size of type page is such that it can be used for new standards in conjunction with present standards for which the type on the present measure is standing, without objectionable appearance. The question of using smaller type was discussed, but the committee was of the opinion that the present standard of the Society is preferable to smaller type from the viewpoint of appearance and ease of reading and it was determined to make no change. A further possible saving lay in the omission of headings from all the standards and tentative standards, it being estimated that this together with the increase in size of type page would result in a reduction of about eight per cent in the number of pages in the Book of Standards and Proceedings for this year.

Recommendations along these lines were made to the Executive Committee and approved. Accordingly all the reports and papers printed for this meeting have been set to the $4\frac{1}{3}$ by 7-in. measure and standards and tentative standards of which the type is now standing will be reset in the new measure whenever they are revised.

The committee has had the heartiest cooperation of authors in its endeavor to reduce the number of pages of the Proceedings devoted to technical papers. In arranging the program it was strongly felt that the number of papers for this meeting should not be reduced materially below that of last year, for to do so would make it impossible for the field of the Society's activities to be adequately covered. Instead, it was the aim to reduce the *average* length of the papers this year about 25 per cent or to approximately 10 printed pages of the new size; and how well the committee has succeeded is shown in the fact that the 22 papers preprinted for this meeting occupy 219 pages, including the summaries which are not published in the Proceedings.

The committee believes that the program of this meeting is one of the strongest and most interesting we have had. Sessions on Concrete, Road Materials and Petroleum Products have been well developed and it is believed that the motion picture on "The Story of Petroleum" secured through the courtesy of the U. S. Bureau of Mines will have great popular as well as technical interest. The program contains 33 reports, including the report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, and 26 papers, including the address of the President. The number of reports is six greater than last year and clearly reflects the growing committee activities. The number of papers offered and suggested was larger than ever before, but the committee could not accept more than it did. A number of offers were received too late for consideration by the committee.

All of the reports and papers announced on the program, with the exception of one report and four papers, have been preprinted for use at the meeting. Twenty-eight reports and seven papers, aggregating 581 pages, were mailed to the members in advance of the meeting. A printers' strike early in May so seriously disrupted the publication schedule that the distribution of all committee reports four weeks in advance of the meeting, as required by the Society's regulations, was found to be impossible, and the distribution of reports containing recommendations with respect to standards was completed two weeks in advance of the meeting. In view of the circumstances, the committee recommends that this requirement be waived for this year in order that these reports may properly come before the annual meeting.

Papers and reports not distributed in advance of the meeting will be sent to any member not attending the meeting who may request copies, as long as the supply on hand lasts.

The total number of pages preprinted this year is 848 compared with 961 last year. (On the basis of the new size of type page, last year's preprints would aggregate approximately 875 pages.)

Several other matters have engaged the attention of the committee during the year. The publication of the A.S.T.M. Bulletin was determined by the Executive Committee upon the recommendation of Committee E-6, which had carefully investigated the entire situation. The committee is undertaking the preparation of an index of the Proceedings from Vols. XIII to XX inclusive (1913–1920) supplementing the index of Vols. I to XII issued in 1912, but has recommended to the Executive Committee that its publication be deferred until conditions are more favorable.

The committee has also given much thought to the policy of the Society regarding the preprinting of reports and papers. After careful consideration of several modifications of this policy, including comparative cost data, it was decided to continue the present policy of preprinting all reports and as many papers as possible. This matter, however, will receive the further consideration of the committee.

This report has been submitted to letter ballot of the committee, which consists of nine members, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

C. L. WARWICK,
Chairman.

REPORT OF COMMITTEE E-8
ON
NOMENCLATURE AND DEFINITIONS.

Committee E-8 was organized by the Executive Committee following the last annual meeting, and this is therefore the first report of the committee. It will be appropriate to refer briefly to the development of definitions of terms in the Society and to show how the need for a committee constituted such as this one has arisen.

The first definitions of terms published by the Society were those relating to structural timber, in 1906. These were followed in 1911 by definitions of terms relating to paint, and in 1912 by terms relating to roads. Terms relating to sewer pipe, gypsum, clay refractories and wrought iron have been defined within recent years. In all the Society has published eight standards and tentative standards devoted entirely to definitions, and in addition there are a number of terms defined separately in specifications. In most of this work there was no coordinated program of development, and definitions were prepared by the respective committees as the need for them developed in their work. It was inevitable that many of these terms should be applicable to fields covered by more than one committee, and some of them have been defined through cooperative efforts of two or more committees. However, within the past two or three years the work of defining terms to be used by the various committees in specifications and methods has been accelerated to such a degree that it has seemed desirable to establish some permanent means of bringing about the desired concerted action of committees in these matters according to a definite, coordinated procedure in which each committee of the Society has its place and responsibility. Moreover, the time has seemed opportune to create a single representative committee charged with the responsibility of developing a program of nomenclature and definitions of terms throughout the broad field covered by the Society, in close cooperation with the standing committees, each of which covers a more or less limited part of that field; and in this way to give proper recognition to an important phase of the Society's activities.

Accordingly, upon the recommendation of Committee E-5 on Standing Committees, which consists of the chairmen of all standing committees, the Executive Committee authorized the appointment of Committee E-8 on Nomenclature and Definitions and announced that fact at the last annual meeting. Each standing committee appointed a representative to serve on the committee, and an organization meeting was held in September, 1920. Details of organization and procedure were fully discussed at this meeting, and at a second meeting held in November, 1920. A review of the field to be covered and study of the nature of the committee's work and the best means of establishing the necessary coordination of that work with the activities of the standing committees, pointed to the desirability of concentrating in the hands of a small advisory committee the executive direction of the committee's work, including the appointment of the necessary sub-committees. It seemed desirable, moreover, that this advisory committee should not consist of members appointed by the standing committees to represent their particular fields and interests, but instead should consist of men appointed by the Executive Committee with special consideration of their interest, experience and ability in the formulation of technical nomenclature and definitions, along the line of organization of Committee E-1 on Methods of Testing, which bears the same relation to that field as does Committee E-8 to its field. The committee has accordingly recommended to the Executive Committee that this plan of organization be given their approval. In the meantime it has prepared regulations to govern its organization and procedure, which, with the approval of the Executive Committee, will be along the following lines: The committee will consist of seven "Members-at-large," appointed by the Executive Committee, who will constitute the advisory committee. The members appointed by the standing committees will be designated "Representative Members." Definitions of terms or a system of nomenclature referred to the committee by one or more standing committees for consideration will be reviewed by a sub-committee which must consist of at least one representative member of Committee E-8 from each standing committee interested in the definitions or nomenclature. The interests of each standing committee in the consideration of the definitions are fully protected by the requirement that any standing committee, upon its request, shall be allowed to designate its representative member to serve on any sub-committee of Committee E-8. In this way the discussion of the details of any definitions, particularly to the end that possible divergent views of several committees may be harmonized, is placed in the hands of the representatives of the committees interested, who are either personally familiar with the definitions under consideration, or who may bring into the sub-committee for advice especially qualified persons from their respective committees. The recommendations of these sub-committees are received and considered by the whole committee and voted upon by letter ballot in accordance with the general Society regulations.

Definite functions have been delegated to the committee by the Executive Committee, as follows:

(*a*) To aid and advise the standing committees in the preparation of Nomenclature and Definitions; in the correlation of similar Nomenclature and Definitions in different committees; and in instituting cooperation between standing committees in matters relating to Nomenclature and Definitions, by the creation of sub-committees of Committee E-8 or otherwise, especially on matters of common interest to a number of standing committees.

(*b*) To encourage, secure and promote, with the approval of the Executive Committee, cooperation in the preparation of Nomenclature and Definitions between standing committees of this Society and the committees of other societies and associations.

(*c*) To perform such other functions as may advance the subject of Nomenclature and Definitions within the scope of the Society's activities.

It is furthermore the duty of the committee to review all definitions and nomenclature prior to their reference to the Society for adoption as standard. It should be clearly understood, however, that each standing committee continues to be responsible for the consideration of matters relating to nomenclature and definitions within the field assigned to it. Many problems will be of such broad application and will concern so many committees that study of them can be most efficiently carried out through Committee E-8 itself, with the active cooperation of the standing committees concerned. This cooperative effort from the very beginning will, in the opinion of the committee, make it possible to prepare definitions more effectively and efficiently than if the several standing committees proceed independently in the preparation of definitions of common interest, leaving it for Committee E-8 to straighten out differences after the committees have gone on record respecting the definitions in their reports to the Society.

The committee has held three meetings, and will meet again during the annual meeting. Much time has of necessity been devoted to matters of organization and procedure, concerning which there are still some details to be developed; but the committee can nevertheless report substantial progress in the technical side of its work.

Index of Terms Defined by the Society.—As the first step towards a comparative study of the definitions of terms that have so far been defined by the Society, there was prepared in the Secretary-Treasurer's office a complete alphabetical index of all such terms, showing the standard in which the definition appears, the location in the Society's publications, and the committee that prepared the definition. This index, which contains 357 terms, has been printed and distributed among the committee members. A preliminary examination of it by a special sub-committee has shown that these definitions may be divided roughly into four classes: (1) Those which, either in their present form or after revision, are suitable for a general glossary; (2) those which are local or special in their application and are of value only in the immediate text of a specification or method; (3) those which seem to be either unnecessary (that is, of common knowledge or readily available in standard reference books) or in conflict with other similar definitions; and (4) a few which do not appear to be definitions at all, but merely recommendations or instructions as to methods.

Further study of this index will be made by the committee, especially with a view to determining the advisability of preparing a glossary of terms and definitions. Where conflicting definitions occur, the committee will endeavor to have uniform definitions prepared by the committees concerned. Several such definitions have already been handled in this way.

Matters Referred to Committee E-8 by Standing Committees.—Committee D-4 on Road Materials has requested the committee to consider the formulation of definitions for the terms "specific gravity," "relative specific gravity" and "apparent specific gravity." This matter, which is one of wide application, has been referred to an appropriate sub-committee for review and recommendations.

Committee C-9 on Concrete and Concrete Aggregates, through its representative on the committee, has requested the committee to consider the formulation of definitions of terms relating to concrete and concrete aggregates. This is a comprehensive subject, involving terms of interest to many committees, and will be undertaken through the organization of a representative sub-committee.

Committee C-11 on Gypsum has referred to the committee a number of definitions of terms relating to the gypsum industry that it will present for acceptance as tentative as this annual meeting. The committee will consider these during the coming year.

Other Problems for Future Consideration.—The field of the committee is a broad one. The committee must review definitions that are now tentative as well as all new ones proposed this year, with a view of reconciling any inconsistencies between them and existing standard definitions and seeing that definitions of broad scope are properly considered by all committees interested. The examination of all existing definitions along lines already begun must be continued and broadened from the viewpoint of ultimately publishing a general glossary. The committee must above all develop a procedure, based upon experience as its work progresses, that will facilitate the preparation of definitions and nomenclature and reduce to a minimum the duplication of effort in the various committees. This can only be done with the hearty cooperation and support of the standing committees, and Committee E-8 earnestly solicits that cooperation and support.

This report has been submitted to letter ballot of the committee, which consists of 35 members, of whom 34 have voted affirmatively, none negatively, and 1 has refrained from voting.

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

C. L. WARWICK,
Ex-Officio Secretary.

A.S.T.M.
TENTATIVE STANDARDS

SUBMITTED OR REVISED

AT THE

1921 ANNUAL MEETING.

The term Tentative Standard is applied to a proposed Standard which is printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action towards its adoption as standard.

Members of the Society and others are invited to direct written criticism of any of these Tentative Standards to the officer of the appropriate committee whose name and address appear in the footnote to the title of each Tentative Standard.

TENTATIVE SPECIFICATIONS

FOR

BOILER AND FIREBOX STEEL FOR STATIONARY SERVICE.[1]

Serial Designation: A 70 – 21 T.

These specifications are issued under the fixed designation A 70; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1916; REVISED, 1917, 1918, 1921.

Material Covered.

1. These specifications cover two classes of steel for boilers for stationary service, namely: flange and firebox.

I. MANUFACTURE.

Process.

2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The steel shall conform to the following requirements as to chemical composition:

		FLANGE.	FIREBOX.	
Carbon	For plates ¾ in. or under in thickness	.....	0.12 – 0.25	per cent
	For plates over ¾ in. in thickness	.....	0.12 – 0.30	"
Manganese	For plates ¾ in. or under in thickness	0.30 – 0.60	0.30 – 0.50	"
	For plates over ¾ in. in thickness	0.30 – 0.60	0.30 – 0.60	"
Phosphorus	Acid	not over 0.05	not over 0.04	"
	Basic	" " 0.04	" " 0.035	"
Sulfur		" " 0.05	" " 0.04	"

Ladle Analyses.

4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. F. M. Waring, Chairman of Committee A-1 on Steel, Pennsylvania System, Altoona, Pa.

composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

Check Analyses. 5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 6. (*a*) The material shall conform to the following requirements as to tensile properties:

	FLANGE AND FIREBOX.
Tensile strength, lb. per sq. in.	55 000 – 65 000
Yield point, min., " "	0.5 tens. str.
Elongation in 8 in., min., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$;

(*b*) Should the above rule for minimum allowable elongation give a value of less than 24 per cent for firebox steel, the minimum allowable elongation shall be 24 per cent, subject to the modifications of Section 7.

(*c*) The yield point shall be determined by the drop of the beam of the testing-machine.

Modifications in Elongation. 7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 20 per cent.

(*b*) For material $\frac{1}{4}$ in. or under in thickness, the elongation shall be measured on a gage length of 24 times the thickness of the specimen.

Bend Tests. 8. The test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

Homogeneity Tests. 9. For firebox steel, a sample taken from a broken tension test specimen shall not show any single seam or cavity more than $\frac{1}{4}$ in. long, in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $\frac{1}{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $\frac{1}{4}$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld up or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the lengths of the seams and cavities determined, a pocket lens being used if necessary.

Test Specimens

10. (*a*) Tension test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimen shall be taken in the direction of the longitudinal axis of the ingot, and the transverse test specimen at right angles to that axis.

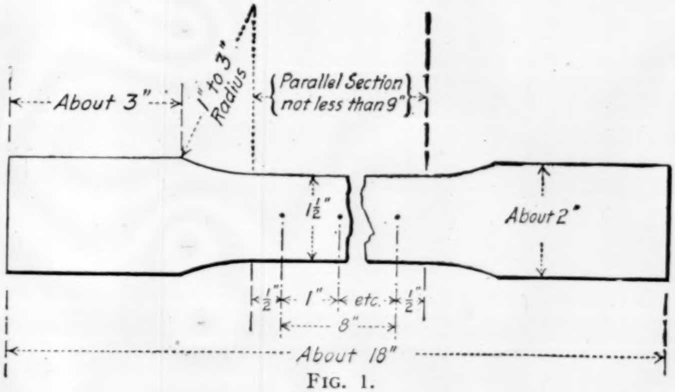

FIG. 1.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

Number of Tests.

11. (*a*) One tension and one bend test shall be made from each plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variations.

12. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

V. FINISH.

Finish.

13. The finished material shall be free from injurious defects and shall have a workmanlike finish.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108in., excl.	108 to 120in., excl.	120 to 132in. excl.	132 in. or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

VI. MARKING.

Marking.

14. (*a*) The name or brand of the manufacturer, melt or slab number, class, and lowest tensile strength for its grade specified in Section 6 (*a*), shall be legibly stamped on each plate. The melt or slab number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When more than one plate is sheared from a single slab or ingot, each shall be match-marked so that they may all be identified with the test specimens representing them.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

(*c*) Each match mark shall consist of two over-lapping circles each not less than 1½ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

VII. INSPECTION AND REJECTION.

Inspection. 15. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 16. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5, shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 17. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
CARBON TOOL STEEL.[1]

Serial Designation: A 71 - 21 T.

These specifications are issued under the fixed designation A 71; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1917; REVISED, 1920, 1921.

Material Covered. 1. These specifications cover three classes of carbon tool steel determined by the chemical composition specified in Section 3.

I. MANUFACTURE.

Process. 2. The steel shall be made by either or both the following process: crucible or electric, with the exception of Class C, which may also be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The steel shall conform to the following requirements as to chemical composition:

ELEMENTS CONSIDERED.	CLASS A.	CLASS B.	CLASS C.
Carbon, per cent	The percentage of carbon may vary by ranges of 0.10 per cent with rejection limits plus or minus 0.025 per cent.[2]	(Same as Class A)	(Same as Class A)
Manganese, max., per cent	0.40	0.45	0.60
Phosphorus, max., per cent	0.02	0.025	0.035
Sulfur, max., per cent	0.025	0.035	0.04
Silicon, max., per cent	0.35	0.35	0.25

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. F. M. Waring, Chairman of Committee A-1 on Steel, Pennsylvania System, Altoona, Pa.

[2] As an illustration, tool steel may be ordered with a carbon range from 0.60 to 0.70 per cent, with rejection limits of 0.575 and 0.725 per cent, or from 0.75 to 0.85 per cent, with rejection of 0.725 and 0.875 per cent.

4. In case of dispute, the chemical analyses shall be made in accordance with the Standard Methods of Chemical Analysis of Plain Carbon Steel (Serial Designation: A 33) of the American Society for Testing Materials.[1] **Chemical Analyses.**

III. PERMISSIBLE VARIATIONS IN DIMENSIONS.

5. The permissible variations in the size of the material ordered shall be agreed upon by the contractor and the purchaser. **Permissible Variations.**

IV. FINISH.

6. The material shall be free from injurious defects, and shall have a workmanlike finish. **Finish.**

V. MARKING.

7. The identification marks to be placed on the material shall be agreed upon by the contractor and the purchaser. **Marking.**

VI. INSPECTION AND REJECTION.

8. The contractor shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. **Inspection.**

9. Material which does not conform to the chemical composition and agreed variations, or which at any time shows injurious defects inherent in the steel, will be rejected, and the contractor shall be notified. **Rejection.**

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[1] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
STEEL PLATES FOR FORGE WELDING.[1]

Serial Designation: A 78 – 21 T.

These specifications are issued under the fixed designation A 78; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1919; REVISED, 1920, 1921.

Material Covered. 1. These specifications apply to steel plates for forge welding for tank cars and for similar construction.

I. MANUFACTURE.

Process. 2. The steel shall be made by the open-hearth process.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. (*a*) The steel shall conform to the following requirements as to chemical composition:

Carbon	for plates $\frac{3}{4}$ in. or under in thickness	not over 0.18	per cent
	for plates over $\frac{3}{4}$ in. in thickness	" " 0.20	"
Manganese		0.40–0.60	"
Phosphorus		not over 0.04	"
Sulfur		" " 0.05	"

(*b*) The composition of steel for forge-welding plates should preferably be free from silicon, nickel or chromium. Where these elements are present the maximum quantity of any one shall not exceed 0.05 per cent.

Ladle Analyses. 4. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of carbon, manganese, phosphorus and sulfur. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 3.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. F. M. Waring, Chairman of Committee A-1 on Steel, Pennsylvania System, Altoona, Pa.

Check Analyses.

5. An analysis may be made by the purchaser from a broken tension test specimen representing each melt. The chemical composition thus determined shall conform to the requirements specified in Section 3.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

6. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	50 000
Yield point, lb. per sq. in.	0.5 tens. str.
Elongation in 8 in., per cent	$\frac{1\,500\,000}{\text{Tens. str.}}$

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation.

7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentage of elongation specified in Section 6 (*a*) of 0.25 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in., to a minimum of 20 per cent.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6 (*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests.

8. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

Test Specimens.

9. (*a*) Test specimens shall be prepared for testing from the material in its rolled condition.

(*b*) Test specimens shall be taken longitudinally and, except as specified in Paragraph (*c*) shall be of the full thickness of material as rolled. They may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

(*c*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*d*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests.

10. (*a*) One tension and one bend test shall be made from each melt; except that if material from one melt differs $\frac{3}{8}$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

IV. PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS.

Permissible Variation. 11. The cross-section or weight of plates shall be covered by the following permissible variations. One cubic inch of rolled steel is assumed to weigh 0.2833 lb.

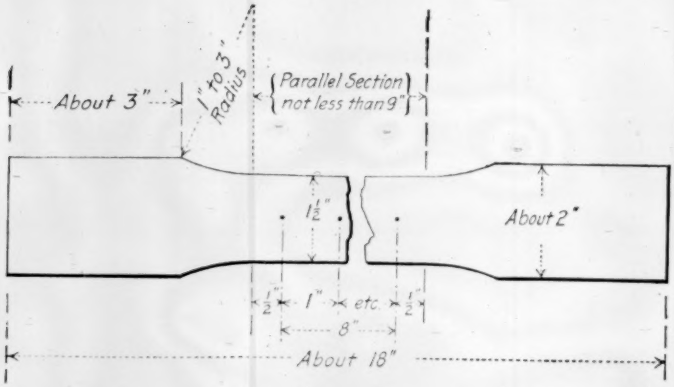

FIG. 1.

(*a*) *When Ordered to Weight per Square Foot:* The weight of each lot[1] in each shipment shall not vary from the weight ordered more than the amount given in Table I.

(*b*) *When Ordered to Thickness:* The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[2] in each shipment shall not exceed the amount given in Table II.

V. FINISH.

Finish. 12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group weight.

[2] The term "lot" applied to Table II means all of the plates of each group width and group thickness.

TABLE I.—PERMISSIBLE VARIATIONS OF PLATES ORDERED TO WEIGHT.

ORDERED WEIGHT, LB. PER SQ. FT.	PERMISSIBLE VARIATIONS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF ORDERED WEIGHTS.																		ORDERED WEIGHT, LB. PER SQ. FT.
	Under 48 in.		48 to 60 in., excl.		60 to 72 in., excl.		72 to 84 in., excl.		84 to 96 in., excl.		96 to 108 in., excl.		108 to 120 in., excl.		120 to 132 in., excl.		132 in. or over.		
	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	Over.	Under.	
Under 5	5	3	5.5	3	6	3	7	3	...	...	...	...	...	...	...	...	...	...	Under 5
5 to 7.5 excl	4.5	3	5	3	5.5	3	6	3	...	...	...	...	...	...	...	...	...	...	5 to 7.5 excl.
7.5 " 10 "	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	...	...	...	...	7.5 " 10 "
10 " 12.5 "	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	9	3	10 " 12.5 "
12.5 " 15 "	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	8	3	12.5 " 15 "
15 " 17.5 "	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	7	3	15 " 17.5 "
17.5 " 20 "	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	6	3	17.5 " 20 "
20 " 25 "	2	2	2.5	2	2.5	2.5	3	2.5	3.5	2.5	4	3	4.5	3	5	3	5.5	3	20 " 25 "
25 " 30 "	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	5	3	25 " 30 "
30 " 40 "	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	4.5	3	30 " 40 "
40 or over	2	2	2	2	2	2	2	2	2.5	2	2.5	2.5	3	2.5	3.5	3	4	3	40 or over

NOTE.—The weight per square foot of individual plates shall not vary from the ordered weight by more than 1¼ times the amount given in this table.

TABLE II.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

ORDERED THICKNESS, IN.	PERMISSIBLE EXCESS IN AVERAGE WEIGHTS PER SQUARE FOOT OF PLATES FOR WIDTHS GIVEN, EXPRESSED IN PERCENTAGES OF NOMINAL WEIGHTS.									ORDERED THICKNESS, IN.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in or over.	
Under 1/8	9	10	12	14	..	..	..	..	..	Under 1/8
1/8 to 3/16 excl.	8	9	10	12	..	..	..	..	..	1/8 to 3/16 excl.
3/16 " 1/4 "	7	8	9	10	12	..	..	..	..	3/16 " 1/4 "
1/4 " 5/16 "	6	7	8	9	10	12	14	16	19	1/4 " 5/16 "
5/16 " 3/8 "	5	6	7	8	9	10	12	14	17	5/16 " 3/8 "
3/8 " 7/16 "	4.5	5	6	7	8	9	10	12	15	3/8 " 7/16 "
7/16 " 1/2 "	4	4.5	5	6	7	8	9	10	13	7/16 " 1/2 "
1/2 " 5/8 "	3.5	4	4.5	5	6	7	8	9	11	1/2 " 5/8 "
5/8 " 3/4 "	3	3.5	4	4.5	5	6	7	8	9	5/8 " 3/4 "
3/4 " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	3/4 " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

VI. MARKING.

Marking. 13. The name or brand of the manufacturer and the melt number shall be legibly rolled or stamped on all finished material. The melt number shall be legibly marked, by stamping if practicable, on each test specimen.

VII. INSPECTION AND REJECTION.

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

COLD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT.[1]

Serial Designation: A 82 - 21 T.

These specifications are issued under the fixed designation A 82; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover cold-drawn steel wire to be used as such, or in fabricated form, for the reinforcement of concrete, in gages not less than 0.080 in. nor greater than 0.500 in.

Basis of Purchase. 2. When wire is ordered by gage number the following relation between number and diameter, in inches, shall apply unless otherwise specified:

Gage. Number	Equivalent Diameter, in.	Gage. Number	Equivalent Diameter, in.
0000000	0.4900	5	0.2070
000000	0.4615	6	0.1920
00000	0.4305	7	0.1770
0000	0.3938	8	0.1620
000	0.3625	9	0.1483
00	0.3310	10	0.1350
0	0.3065	11	0.1205
1	0.2830	12	0.1055
2	0.2625	13	0.0915
3	0.2437	14	0.0800
4	0.2253		

I. MANUFACTURE.

Process. 3. (*a*) The steel shall be made by either or both the following processes: Bessemer or open hearth.

Drawing. (*b*) The wire shall be cold drawn from rods hot-rolled from billets.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. F. M. Waring, Chairman of Committee A-1 on Steel, Pennsylvania System, Altoona, Pa.

II. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 4. (*a*) The wire, except as specified in Paragraphs (*b*) and (*c*), shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	80,000
Reduction of area, per cent	30

(*b*) For wire to be used in the fabrication of mesh a minimum tensile strength of 70,000 lb. per sq. in. shall be permitted.

(*c*) For wire testing over 100,000 lb. per sq. in. tensile strength, the reduction of area shall be not less than 25 per cent.

Bend Tests. 5. The test specimen shall withstand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows:

For wire 0.3 in. in diameter or under, around a pin the diameter of which is equal to the diameter of the specimen.

For wire over 0.3 in. in diameter, around a pin the diameter of which is equal to twice the diameter of the specimen.

Test Specimens. 6. Tension and bend test specimens shall be of the full-size section of the wire as drawn.

Number of Tests. 7. (*a*) One tension and one bend test shall be made for each 10 tons or less of each size of wire.

(*b*) If any test specimen shows defects or develops flaws, it may be discarded and another specimen substituted.

III. PERMISSIBLE VARIATIONS IN GAGE.

8. The diameter of the wire shall not vary more than 0.003 in. from the size ordered.

IV. WORKMANSHIP AND FINISH.

9. The finished wire shall be free from injurious defects and shall have a workmanlike finish with smooth surface.

V. INSPECTION AND REJECTION.

Inspection. 10. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. Wire which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

TENTATIVE SPECIFICATIONS

FOR

LAP-WELDED AND SEAMLESS STEEL AND LAP-WELDED IRON BOILER TUBES.[1]

Serial Designation: A 83 - 21 T.

These specifications are issued under the fixed designation A 83; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Note.—In the following specifications attention is called to the basis on which tubes are gaged for thickness. No variation beneath the ordered gage is allowed, all variations being on the side of thicker than ordered gage. Present standard A.S.T.M. specifications for locomotive tubes permit of variation above and below the ordered gage. The present A.S.T.M. standard specifications for stationary service, as well as Boiler Code and Marine specifications, do not permit of tubes being less than the ordered gage. Where previously used specifications permit of tubes less than the ordered gage, the purchaser in using these tentative specifications must order tubes one gage lighter than formerly to obtain the same weight and gage of tubes. For example: where 2 in. o.d. No. 11 B.w.g. cold-drawn tubes were previously ordered, 2 in. o.d. No. 12 B.w.g. should be ordered to these specifications. Tubes would be furnished which would have an average thickness of No. 11 B.w.g. They would not be less than No. 12 B.w.g. but might be No. 10 B.w.g. They would have the same nominal weight as under the previous system.

Material Covered. 1. These specifications cover lap-welded and seamless steel and lap-welded iron boiler tubes, boiler flues, superheater tubes, safe ends and arch tubes.

I. MANUFACTURE.

Process. 2. (*a*) The material for lap-welded tubes shall be made by the open-hearth process, or by the knobbled, hammered charcoal iron process.

(*b*) The material for seamless tubes shall be made by the open-hearth process.

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[1] Criticism of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. F. M. Waring, Chairman of Committee A-1 on Steel, Pennsylvania System, Altoona, Pa.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

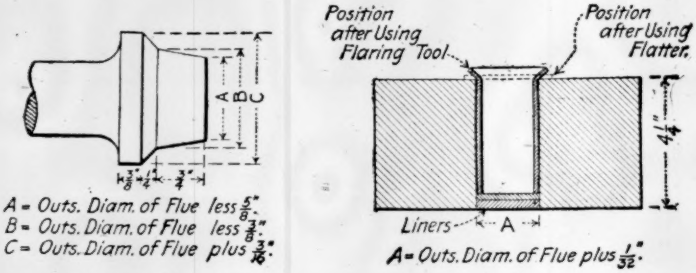
3. (*a*) Chemical analysis will not be required for charcoal iron tubes.

(*b*) Material made by the open-hearth process shall conform to the following requirements as to chemical composition:

		Grade A.	Grade B.
Carbon,	per cent	0.08 – 0.18	not over 0.03
Manganese,	"	0.30 – 0.60	" " 0.03
Phosphorus,	"	not over 0.04	" " 0.02
Sulfur,	"	" " 0.045	" " 0.045

Check Analyses.

4. (*a*) Analyses of two tubes in each lot of 250 tubes or less, and of 2000 feet or less of safe-end material, may be made by the purchaser. The chemical composition thus determined shall conform to the requirements specified in Section 3 (*b*). Drillings for analysis shall be taken from several points around each tube.


A
B
C
3/8"
1/4"
3/4"
A = Outs. Diam. of Flue less 5/8".
B = Outs. Diam. of Flue less 3/8".
C = Outs. Diam. of Flue plus 3/16".
Position after Using Flaring Tool
Position after Using Flatter.
4 1/4"
Liners
A
A = Outs. Diam. of Flue plus 1/32".

Flaring Tool.

Die Block.

FIG. 1

(*b*) If the analysis of only one tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

III. PHYSICAL PROPERTIES AND TESTS.

5. Tubes of material made by the open-hearth process shall meet the tests specified for steel tubes.

Flange Tests.

6. (*a*) For tubes not more than 6 in. in diameter and having a thickness less than 10 per cent of the outside diameter, provided the thickness does not exceed No. 6 B.w.g. (0.203 in.), a test specimen not less than 4 in. in length shall have a flange turned over at right angles to the body of the tube without cracking or showing any flaw. This flange, as measured from the outside of tube, shall in no case be less than $\frac{1}{8}$ in. nor more than $\frac{1}{2}$ in. Within these limits the width of

flange shall be not less than 10 per cent of the outside diameter for charcoal-iron, nor less than 15 per cent for steel tubes up to $2\frac{1}{2}$ in., inclusive. For steel tubes over $2\frac{1}{2}$ in. in diameter and up to $3\frac{3}{4}$ in., inclusive, the width of the flange shall be $\frac{3}{8}$ in., and for tubes over $3\frac{3}{4}$ in. the width of flange shall be 10 per cent of the outside diameter.

(*b*) For tubes not specified in Paragraph (*a*) the flange test will not be required.

(*c*) In making the flange test, it is recommended that the flaring tool and die block as shown in Fig. 1 be used.

Flattening Test.

7. (*a*) For all tubes, except when the wall thickness is in excess of 10 per cent of the outside diameter, providing the thickness does not exceed No. 6 B.w.g. (0.203 in.), a test specimen 3 in. in length shall withstand flattening between parallel plates, without cracking or showing any flaw, until the distance between the plates is as follows:

Three times the wall thickness for seamless tubes;
Five times the wall thickness for lap-welded tubes.

NOTE.—In the case of lap-welded tubes, the test shall be made with the weld at the point of maximum bend.

(*b*) For all tubes not specified in Paragraph (*a*) a test specimen 3 in. in length shall withstand flattening between parallel plates, without cracking or showing any flaw, until the distance between the plates is as follows:

Four times the wall thickness for seamless tubes;
Six times the wall thickness for lap-welded tubes.

NOTE.—In the case of lap-welded tubes, the test shall be made with the weld at the point of maximum bend.

Crush Tests.

8. When required by the inspector, crushing tests shall be made on test specimens $2\frac{1}{2}$ in. in length, which shall withstand crushing longitudinally, without cracking, splitting or opening at the weld, as follows:

Steel tubes: No. 10 B.w.g. or lighter to a height of $\frac{3}{4}$ in. or until outside folds are in contact; if heavier than No. 10 B.w.g. to a height of $1\frac{1}{4}$ in.
Charcoal-iron tubes: No. 10 B.w.g. or lighter, to a height of $1\frac{1}{8}$ in.; if heavier than No. 10 B.w.g., to a height of $1\frac{3}{4}$ in.

Hydrostatic Tests.

9. Tubes under 5 in. in diameter shall withstand an internal hydrostatic pressure of 1000 lb. per sq. in. and tubes 5 in. or over in diameter shall withstand an internal hydrostatic pressure of 800 lb. per sq. in.; provided that the fiber stress corresponding to these

TABLE I.—STANDARD WEIGHTS OF LAP-WELDED AND SEAMLESS BOILER TUBES.

INCLUDING SAFE ENDS, ARCH TUBES AND LARGE BOILER TUBES.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.																						
B.w.g	In.	1¾	2	2¼	2½	2¾	3	3¼	3½	3¾	4	4½	5	5¼	5⅜	5½	6	7	8	9	10	11	12	13
13	0.095	1.679	1.932	2.186	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	1.910	2.201	2.492	2.783	3.074	3.365	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	0.120	2.089	2.409	2.729	3.050	3.370	3.691	4.011	4.331	4.652	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10	0.134	2.312	2.670	3.028	3.386	3.743	4.101	4.459	4.817	5.175	5.532	6.248	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	0.148	2.532	2.927	3.322	3.717	4.112	4.508	4.903	5.298	5.693	6.088	6.879	7.669	8.064	8.262	8.459	.....	.....	.....	.....	.....	.....	.....	.....
8	0.165	.....	3.233	.....	4.114	4.555	4.995	5.436	5.877	6.317	6.758	7.639	8.520	8.960	9.181	9.401	10.282	12.044	13.807	.....	.....	.....	.....	.....
7	0.180	.....	.....	.....	4.460	4.940	5.421	5.901	6.382	6.863	7.343	8.304	9.266	9.746	9.987	10.227	11.188	13.110	15.033	16.955	.....	.....	.....	.....
6	0.203	.....	.....	.....	4.980	5.522	6.064	6.606	.....	.....	8.232	9.316	10.400	.....	.....	.....	12.568	14.736	16.904	19.072	21.240	.....	.....	.....
5	0.220	.....	.....	.....	5.357	5.944	6.531	7.119	.....	.....	.....	.....	11.231	.....	.....	.....	13.580	15.930	18.280	20.629	22.979	25.329	.....	.....
4½	0.229	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	28.788	.....
4	0.238	.....	.....	.....	5.749	6.385	7.020	7.656	.....	.....	.....	.....	.....	.....	.....	.....	14.646	17.188	19.730	22.271	24.813	27.355	.....	32.439
3½	0.2485	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	31.188	.....
3	0.259	.....	4.815	5.507	6.198	6.890	7.582	8.273	8.965	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	24.179	26.945	29.711	.....	35.243
2½	0.2715	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.008	.....
2	0.284	.....	.....	.....	6.721	.....	8.238	8.990	9.754	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	29.470	32.503	.....	38.569
1½	0.292	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	36.512	.....
1	0.300	.....	.....	.....	7.048	7.849	8.650	9.451	10.252	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	34.283	.....	40.69
½	0.320	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	39.918	.....
0	0.340	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	45.971

NOTE.—Seamless tubes are at present not available above 6 in. in outside diameter.

pressures does not exceed 16,000 lb. per sq. in. Should the fiber stress corresponding to these pressures exceed 16,000 lb. per sq. in., the test pressure shall be determined by the formula:

$$P = \frac{32{,}000\, t}{D}$$

in which P = the pressure in pounds per square inch, t = the thickness of wall in inches, and D = the inside diameter of the tube in inches. Lap-welded tubes shall be struck near both ends, while under the test pressure, with a 2-lb. steel hand hammer or the equivalent.

Etch Tests for Charcoal-Iron Tubes.

10. A cross-section of charcoal-iron tubes may be turned or ground to a true surface, polished free from dirt or cracks, and etched[1] until the soft parts are sufficiently dissolved for the iron tube to show a decided ridged surface, with the weld very distinct, while a steel tube would show a homogeneous surface.

Test Specimens.

11. Test specimens shall be taken from finished tubes. They shall be smooth on the ends and free from burrs. All specimens shall be tested cold.

Number of Tests.

12. Each tube shall be subjected to the hydrostatic test. One of each of the physical tests specified shall be made from each of two tubes in each lot of 250 or less, and each 2000 feet or less of safe end material.

Retests.

13. If the results of the physical tests of only one tube from any lot do not conform to the requirements specified in Sections 6, 7 and 8, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

IV. STANDARD WEIGHTS.

Standard Weight.

14. The standard weights for tubes of various outside diameters and thicknesses are as indicated in Tables Nos. I and II.

Permissible Variation.

15. The weight of any tube shall not be less than that shown in Tables Nos. I and II.

V. WORKMANSHIP AND FINISH.

Workmanship.

16. (*a*) Finished tubes 4 in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 4 in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

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[1] A solution of two parts water, one part HCl (sp. gr. 1.20), and one part H_2SO_4 (sp. gr. 1.84) s recommended for the etch test.

(*b*) Tubes shall be gaged with a Birmingham wire gage, and shall be not less than the thickness specified, except that tubes will be accepted on which the gage will go on tightly at the thinnest point.

(*c*) Cold-drawn tubes shall not, at any place, exceed the specified thickness by more than two gages.

(*d*) Hot-finished tubes shall not, at any place, exceed the specified thickness by more than three gages.

(*e*) The length shall not be less but may be $\frac{3}{16}$ in. more than that specified.

Finish. 17. Finished tubes shall be free from injurious defects and distortion, shall have smooth ends free from burrs and shall have a workmanlike finish.

TABLE II.—STANDARD WEIGHTS OF SMALL SUPERHEATER TUBES.
SEAMLESS ONLY.

THICKNESS.		WEIGHT, LB. PER FT. OF LENGTH. Outside Diameter, in.											
B.w.g.	In.	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{5}{8}$
14	0.083	0.480	0.535	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
13	0.095	0.537	0.601	0.664	0.727	.....	.....	.....	.....	.....	.....	.....	.....
12	0.109	.....	.....	0.746	0.818	0.891	.....	.....	.....	.....	.....	.....	.....
11	0.120	.....	.....	.....	0.887	0.967	1.047	1.127	.....	.....	.....	.....	.....
10	0.134	.....	.....	.....	.....	1.060	1.149	1.239	1.597	1.776	1.865	1.954	2.133
9	0.148	.....	.....	.....	.....	.....	1.247	1.346	1.741	1.939	2.038	2.138	2.334
8	0.165	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	2.352	.....

VI. MARKING.

Marking. 18. The name or brand of the manufacturer, the material from which it is made, whether steel or iron, and the pressure in pounds at which it was tested, shall be legibly stenciled on each tube.

VII. INSPECTION AND REJECTION.

Inspection. 19. (*a*) Unless otherwise specified, inspection and all tests, except check analyses, shall be made at the place of manufacture. When required, the manufacturer shall furnish the purchaser of each lot of tubes a statement as to the kind of material of which the tubes are made and that the tubes have been tested and have met all the requirements of these specifications.

(*b*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tubes ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tubes are being furnished in accordance with these specifications.

Rejection. 20. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 4 (*a*) shall be reported within five working days from the receipt of samples.

(*b*) Tubes when inserted in the boiler shall stand expanding and beading without showing cracks or flaws, or opening at the weld. Superheater tubes when properly manipulated shall stand all forging, welding, and bending operations necessary for application without developing defects. Tubes which fail in any of the above operations will be rejected, and the manufacturer shall be notified.

Rehearing. 21. Samples tested in accordance with Section 4 (*a*) which represent rejected tubes, shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
IRON AND STEEL CHAIN.[1]

Serial Designation: A 56 – 21 T.

These specifications are issued under the fixed designation A 56; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

I. MATERIAL AND MANUFACTURE.

Material Covered. 1. (*a*) These specifications cover five classes of iron and steel chain.

(*b*) The purposes for which these classes are generally used and the trade designations are as follows:

Class AA, for slings, cranes, hoists, steam shovels, and marine uses, and where an all-iron chain is desired.

Class A, for slings, cranes, hoists, steam shovels and marine uses where a high quality chain is desired and sold under the trade designation "Dredge Chain."

Class B, for ordinary slings and hoists and sold under the trade designation "B.B.B."

Class C, for railroad cars, construction and forestry work and sold under the trade designation "B.B." or Railroad Chain.

Class D, for general service and sold under the trade designation "Proof Coil" or "Common Coil Chain."

Material. 2. The material entering into the five classes of chain shall be as follows:

Class AA.—Wrought-iron chain. The wrought iron shall be made wholly from all pig puddled iron free from any admixture of iron scrap or steel.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

Class A.—Wrought-iron chain. The wrought iron shall be made from all pig puddled iron or a mixture of puddled iron and reworked scrap.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Iron and Steel Chain. The Standard Specifications, which were last issued under the Serial Designation: A 56-18, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. J. B. Young, Secretary of Committee A-2 on Wrought Iron, Philadelphia and Reading Railway Co., Reading, Pa.

Class B.—Wrought-iron or open-hearth steel chain. The wrought iron may be made from a mixture of all pig puddled iron and reworked scrap or from all reworked scrap. Unless otherwise specified, chain $\frac{1}{2}$-in. and smaller may be made from open-hearth steel.

Class C.—Wrought-iron or open-hearth steel chain. The wrought iron may be made from all reworked scrap. Unless otherwise specified, chain $\frac{1}{2}$ in. and smaller may be made from open-hearth steel.

Class D.—Wrought-iron or open-hearth steel chain. The wrought iron may be made from all reworked scrap.

NOTE.—The term "reworked scrap" applies to steel and iron scrap, or a mixture of both.

Welding. 3. Classes AA and A chain shall be lap-fire-welded. Unless otherwise specified, Classes B, C and D, may be made by either fire or electric welding processes.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 4. The wrought iron and steel of the respective classes of chain shall conform to the following requirements as to chemical composition:

	IRON.		STEEL.
	CLASS AA.	CLASS A.	CLASS A AND B.
Manganese, per cent, not over	0.10	0.20	...
Phosphorus, " " "	....	....	.04
Sulfur, " " "	....	....	.04

Check Analyses. 5. (*a*) Analyses may be made by the purchaser from the bars or from the finished chain. The chemical composition thus determined shall conform to the requirements specified in Section 4.

(*b*) Drillings for analysis shall be taken with a drill the diameter of which is approximately one-half the diameter of the bar from which drillings are taken, and the cuttings shall be taken through the bar from surface to surface.

III. PHYSICAL PROPERTIES AND TESTS.

Proof Tests. 6. (*a*) All chain shall be proof tested by subjecting it to the loads shown in Table I, and when so tested it shall stand these loads without showing any defects.

(*b*) When requested, the manufacturer shall furnish a certificate of proof test to the purchaser or his representative.

Tension Tests. 7. (*a*) Samples from finished chain shall conform to the minimum requirements as to tensile strength specified in Table II.

(*b*) The elongation, determined in a gage length of from 12 to 18 in. to the nearest link, shall conform to the following minimum requirements for the respective classes:

Classes AA and A	15 per cent
Class B	15 "
Class C	12 "
Class D	10 "

TABLE I.—PROOF TESTS.

Nominal Size of Chain Bar, in.	Proof Test Loads, lb			
	Class AA "W.I." and Class A "Dredge" Iron	Class B "B.B.B." Iron or Steel.	Class C "B.B." Iron or Steel.	Class D "Proof Coil" Iron or Steel.
$\frac{1}{4}$	....	1 850	1 700	1 550
$\frac{5}{16}$	....	2 850	2 650	2 450
$\frac{3}{8}$	4 350	4 100	3 850	3 500
$\frac{7}{16}$	5 950	5 600	5 250	4 800
$\frac{1}{2}$	7 800	7 300	6 850	6 250
$\frac{9}{16}$	9 900	9 250	8 650	7 950
$\frac{5}{8}$	12 150	11 400	10 700	9 800
$\frac{11}{16}$	14 700	13 800	12 900	11 850
$\frac{3}{4}$	17 500	16 450	15 350	14 100
$\frac{13}{16}$	20 550	19 300	18 050	16 550
$\frac{7}{8}$	23 800	22 350	20 900	19 200
$\frac{15}{16}$	27 350	25 700	24 050	22 050
1	31 100	29 200	27 350	25 050
$1\frac{1}{8}$	39 350	37 000	34 600	31 700
$1\frac{1}{4}$	48 600	45 700	42 700	39 150
$1\frac{3}{8}$	58 800	.....	.....	.....
$1\frac{1}{2}$	70 000	.....	.....	.....
$1\frac{5}{8}$	81 500	.....	.....	.....
$1\frac{3}{4}$	93 900	.....	.....	.....
$1\frac{7}{8}$	107 100	.....	.....	.....
2	121 150	.....	.....	.....

Test Specimens. 8. Tension test specimens shall consist of a length not less than 2 ft., cut from the finished chain.

Number of Tests. 9. One tension test shall be made to represent each lot of 200 ft. of chain or fraction thereof ordered.

Retests. 10. If the tension test fails to conform to the requirements specified in Section 7, two additional tension tests may be made from the same lot, each of which shall meet the requirements of Section 7.

Etch Tests.

11. *Class AA.*—The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. The test shall show the material to be free from steel.

NOTE.—A solution of two parts water, one part HCl (sp. gr. 1.20), and one part H_2SO_4 (sp. gr. 1.84) is recommended for the etch test.

TABLE II.—TENSILE STRENGTH.

Nominal Size of Chain Bar, in.	Breaking Load, lb.			
	Class AA "W.I." and Class A "Dredge" Iron.	Class B "B.B.B." Iron or Steel.	Class C "B.B." Iron or Steel.	Class D "Proof Coil" Iron or Steel.
$\frac{1}{4}$	....	3 700	3 400	3 100
$\frac{5}{16}$	......	5 700	5 300	4 900
$\frac{3}{8}$	8 700	8 200	7 700	7 000
$\frac{7}{16}$	11 900	11 200	10 500	9 600
$\frac{1}{2}$	15 600	14 600	13 700	12 500
$\frac{9}{16}$	19 800	18 500	17 300	15 900
$\frac{5}{8}$	24 300	22 800	21 400	19 600
$\frac{11}{16}$	29 400	27 600	25 800	23 700
$\frac{3}{4}$	35 000	32 900	30 700	28 200
$\frac{13}{16}$	41 100	38 600	36 100	33 100
$\frac{7}{8}$	47 600	44 700	41 800	38 400
$\frac{15}{16}$	54 700	51 400	48 100	44 100
1	62 200	58 400	54 700	50 100
$1\frac{1}{8}$	78 700	74 000	69 200	63 400
$1\frac{1}{4}$	97 200	91 400	85 400	78 300
$1\frac{3}{8}$	117 600	.....	.....	.....
$1\frac{1}{2}$	140 000	.....	.....	.....
$1\frac{5}{8}$	163 000	.....	.....	.....
$1\frac{3}{4}$	187 800	.....	.....	.....
$1\frac{7}{8}$	214 200	.....	.....	.....
2	242 300	.....	.....	.....

IV. STANDARD WEIGHTS AND DIMENSIONS.

Nominal Weights and Lengths.

12. (*a*) The nominal weights of 100 ft., nominal lengths of 100 links and nominal dimensions of links for chain of various sizes are given in Table III.

(*b*) The weights and lengths of 100 links of chain shall not vary more than 4 per cent over nor more than 4 per cent under the nominal weight and lengths specified in Table III. Excess weight over the

TABLE III.—MAXIMUM LENGTHS AND NOMINAL WEIGHTS AND DIMENSIONS.

Nominal Size of Chain Bar, in.	Actual Size of Material in.	Nominal Length of 100 Links, in.		Nominal Weight per 100 ft., lb.			Nominal Dimensions of Links, in.											
							Class B (B.B.B.).				Class C (B.B.).				Class D (Proof Coil).			
							Outside.		Inside.		Outside.		Inside.		Outside.		Inside.	
		Class B (B.B.B.).	Class C (B.B.).	Class B (B.B.B.).	Class C (B.B.).	Class D (Proof Coil).	Length.	Width.	Length.	Width.	Length.	Width.	Length.	Width.	Length.	Width.	Length.	Width.
$\frac{1}{4}$	$\frac{9}{32}$	88	100	75	70	74	$1\frac{3}{8}$	$\frac{15}{16}$	$\frac{13}{16}$	$\frac{3}{8}$	$1\frac{7}{16}$	$\frac{15}{16}$	$\frac{7}{8}$	$\frac{7}{16}$	$1\frac{1}{2}$	$1\frac{1}{16}$	$\frac{15}{16}$	$\frac{1}{2}$
$\frac{5}{16}$	$\frac{11}{32}$	105	114	110	105	110	$1\frac{19}{32}$	$1\frac{5}{32}$	$\frac{29}{32}$	$\frac{15}{32}$	$1\frac{11}{16}$	$1\frac{5}{32}$	1	$\frac{15}{32}$	$1\frac{3}{4}$	$1\frac{1}{4}$	$1\frac{1}{16}$	$\frac{9}{16}$
$\frac{3}{8}$	$\frac{13}{32}$	113	125	165	155	155	$1\frac{29}{32}$	$1\frac{3}{8}$	$1\frac{3}{32}$	$\frac{9}{16}$	$1\frac{31}{32}$	$1\frac{3}{8}$	$1\frac{5}{32}$	$\frac{9}{16}$	$2\frac{1}{16}$	$1\frac{7}{16}$	$1\frac{1}{4}$	$\frac{5}{8}$
$\frac{7}{16}$	$\frac{15}{32}$	125	137	210	200	204	$2\frac{3}{16}$	$1\frac{9}{16}$	$1\frac{1}{4}$	$\frac{5}{8}$	$2\frac{9}{32}$	$1\frac{19}{32}$	$1\frac{11}{32}$	$\frac{21}{32}$	$2\frac{3}{8}$	$1\frac{11}{16}$	$1\frac{7}{16}$	$\frac{3}{4}$
$\frac{1}{2}$	$\frac{17}{32}$	144	150	270	255	260	$2\frac{1}{2}$	$1\frac{25}{32}$	$1\frac{7}{16}$	$\frac{23}{32}$	$2\frac{19}{32}$	$1\frac{13}{16}$	$1\frac{17}{32}$	$\frac{3}{4}$	$2\frac{11}{16}$	$1\frac{7}{8}$	$1\frac{5}{8}$	$\frac{13}{16}$
$\frac{9}{16}$	$\frac{19}{32}$	160	169	330	310	328	$2\frac{25}{32}$	2	$1\frac{19}{32}$	$\frac{13}{16}$	$2\frac{7}{8}$	2	$1\frac{11}{16}$	$\frac{13}{16}$	3	$2\frac{1}{16}$	$1\frac{13}{16}$	$\frac{7}{8}$
$\frac{5}{8}$	$\frac{21}{32}$	175	187	425	400	405	$3\frac{1}{16}$	$2\frac{3}{16}$	$1\frac{3}{4}$	$\frac{7}{8}$	$3\frac{3}{16}$	$2\frac{1}{4}$	$1\frac{7}{8}$	$\frac{15}{16}$	$3\frac{5}{16}$	$2\frac{5}{16}$	2	1
$\frac{11}{16}$	$\frac{23}{32}$	188	200	525	500	484	$3\frac{3}{8}$	$2\frac{13}{32}$	$1\frac{15}{16}$	$\frac{31}{32}$	$3\frac{1}{2}$	$2\frac{15}{32}$	$2\frac{1}{16}$	$1\frac{1}{32}$	$3\frac{5}{8}$	$2\frac{1}{2}$	$2\frac{3}{16}$	$1\frac{1}{16}$
$\frac{3}{4}$	$\frac{25}{32}$	200	217	600	575	583	$3\frac{21}{32}$	$2\frac{5}{8}$	$2\frac{3}{32}$	$1\frac{1}{16}$	$3\frac{25}{32}$	$2\frac{21}{32}$	$2\frac{7}{32}$	$1\frac{3}{32}$	$3\frac{15}{16}$	$2\frac{3}{4}$	$2\frac{3}{8}$	$1\frac{3}{16}$
$\frac{13}{16}$	$\frac{27}{32}$	217	232	700	650	671	$3\frac{15}{16}$	$2\frac{13}{16}$	$2\frac{1}{4}$	$1\frac{1}{8}$	$4\frac{3}{32}$	$2\frac{7}{8}$	$2\frac{13}{32}$	$1\frac{3}{16}$	$4\frac{1}{4}$	3	$2\frac{9}{16}$	$1\frac{5}{16}$
$\frac{7}{8}$	$\frac{29}{32}$	235	247	800	775	775	$4\frac{1}{4}$	$3\frac{1}{32}$	$2\frac{7}{16}$	$1\frac{7}{32}$	$4\frac{3}{8}$	$3\frac{3}{32}$	$2\frac{9}{16}$	$1\frac{9}{32}$	$4\frac{9}{16}$	$3\frac{3}{16}$	$2\frac{3}{4}$	$1\frac{3}{8}$
$\frac{15}{16}$	$\frac{31}{32}$	248	263	900	875	880	$4\frac{17}{32}$	$3\frac{7}{32}$	$2\frac{19}{32}$	$1\frac{9}{32}$	$4\frac{11}{16}$	$3\frac{9}{32}$	$2\frac{3}{4}$	$1\frac{11}{32}$	$4\frac{7}{8}$	$3\frac{3}{8}$	$2\frac{15}{16}$	$1\frac{7}{16}$
1	$\frac{33}{32}$	262	280	1 000	975	1 000	$4\frac{13}{16}$	$3\frac{7}{16}$	$2\frac{3}{4}$	$1\frac{3}{8}$	5	$3\frac{1}{2}$	$2\frac{15}{16}$	$1\frac{7}{16}$	$5\frac{3}{16}$	$3\frac{5}{8}$	$3\frac{1}{8}$	$1\frac{9}{16}$
$1\frac{1}{8}$	..	300	320	1 300	1 250	....	....	....	....	....	....	....	....	....	....	....	....	....
$1\frac{1}{4}$	..	350	369	1 600	1 500	....	....	....	....	....	....	....	....	....	....	....	....	....
$1\frac{3}{8}$	..	381	...	1 950	....	....	....	....	....	....	....	....	....	....	....	....	....	....
$1\frac{1}{2}$	..	412	...	2 300	....	....	....	....	....	....	....	....	....	....	....	....	....	....
$1\frac{5}{8}$	..	444	...	2 600	....	....	....	....	....	....	....	....	....	....	....	....	....	....
$1\frac{3}{4}$	..	475	...	3 000	....	....	....	....	....	....	....	....	....	....	....	....	....	....
$1\frac{7}{8}$	..	525	...	3 500	....	....	....	....	....	....	....	....	....	....	....	....	....	....
2	..	575	...	4000	....	....	....	....	....	....	....	....	....	....	....	....	....	....

NOTE.—(*a*) Classes AA and A being ordered to special dimensions, the weight and dimensions are not provided except that when crane chain is specified under Class A, the length of 100 links and the nominal weight per 100 ft. shall be in accordance with Class B in Table III.

(*b*) **Class D. Ordinary chain, various lengths of links used, dimensions and weights given are approximate only.**

permissible variations of 4 per cent may be cause for rejection. All chain accepted shall be paid for at actual weight.

(c) The length shall be measured after the chain has been proof tested,and shall be measured to the inside of the end links.

(d) In determining the length of the chain, a load not exceeding 10 per cent of the proof load specified in Table I shall be applied to take up the slack.

V. WORKMANSHIP AND FINISH.

Workmanship and Finish

13. (a) The chain shall be free from injurious defects and shall have a workmanlike finish. The diameter of the bar in all chain shall not be less than nominal size in the body and welds, and unless otherwise specified, the weld shall not exceed the diameter of the bar more than 25 per cent.

(b) Prior to testing and inspection the chain shall be free from paint or other coating which would tend to conceal defects.

VI. INSPECTION AND REJECTION.

Inspection.

14. (a) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the chain ordered. The manufacturer shall afford the inspector, free of charge, all reasonable facilities to satisfy him that the chain is being furnished in accordance with these specifications.

(b) Unless otherwise specified, all tests and inspection shall be made at the place of manufacture; but when specified by the purchaser he may make the tests and inspection to govern the acceptance or rejection of the chain at his own laboratory or elsewhere at his own expense.

(c) Tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (b) shall be reported within five working days from receipt of samples.

Rehearing.

16. Samples tested in accordance with Section 14 (b), which represent rejected chain, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
MERCHANT BAR IRON.[1]

Serial Designation: A 85 – 21 T.

These specifications are issued under the fixed designation A 85; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

I. MANUFACTURE.

Process. 1. Merchant bars may be made from reworked iron scrap or a reworked mixture of iron and steel scrap, but shall be free from large areas of steel.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 2. The bars shall conform to the following requirements as to chemical composition:

Manganese	not over 0.30 per cent.

Check Analysis. 3. (*a*) An analysis may be made by the purchaser from a broken tension test specimen representing each lot as specified in Section 11. The chemical composition thus determined shall conform to the requirement specified in Section 2.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests. 4. (*a*) The bars shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	48 000
Yield point, lb. per sq. in.	25 000
Elongation in 8 in., per cent	22

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. J. B. Young, Secretary of Committee A-2 on Wrought Iron, Philadelphia and Reading Railway Co., Reading, Pa.

(*c*) *Fracture Test.*—The broken ends of the tension test specimen shall show a uniform fibrous structure similar to that of wrought iron.

Modifications in Tensile Strength.

5. For material over 4 sq. in. in sectional area, a reduction of 250 lb. per sq. in. from the tensile strength specified in Section 4 will be permitted for each additional square inch, and a proportionate amount of reduction for fractional parts thereof; provided that the tensile strength shall not be less than 45,000 lb. per sq. in.

Permissible Variations in Tensile Strength.

6. Twenty per cent of the test specimens representing one size may show tensile strengths 1000 lb. per sq. in. under or 5000 lb. per sq. in. over that specified in Sections 4 and 5; but no specimen shall show a tensile strength less than 45,000 lb. per sq. in.

Permissible Variations in Elongation.

7. Twenty per cent of the test specimens representing one size may show the following percentages of elongation in 8 in.:

ROUND BARS.

Tested as rolled	½ in. or over	20 per cent
	Under ½ in.	16 "
Reduced by machining		18 "

FLAT BARS.

Tested as rolled	⅜ in. or over	18 per cent
	Under ⅜ in.	16 "
Reduced by machining		16 "

Bend Tests.

8. (*a*) *Cold-Bend Tests.*—Cold-bend tests will be made only on bars having a nominal area of 4 sq. in. or under, in which case the test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to twice the diameter or thickness of the specimen.

(*b*) *Hot-Bend Tests.*—The test specimen, when heated to a temperature between 1700 and 1800 ° F., shall withstand being bent through 180 deg. without fracture on the outside of the bent portion, as follows:—For round bars under 2 sq. in. in section, flat on itself; for round bars 2 sq. in. or over in sections and for all flat bars, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

(*c*) *Nick-Bend Tests.*—The test specimen, when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60-deg. cutting edge, to a depth of not less than 8 or more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show not more than 10 per cent of the fractured surface to be crystallin.

(*d*) Bend tests may be made by pressure or by blows.

Etch Tests.

9. The cross-section of the test specimen shall be ground or polished and etched for a sufficient period to develop the structure.

This test shall show the material to be of a uniform structure similar to wrought iron.

Test Specimens.

10. (*a*) Tension and bend test specimens shall be of the full section of material as rolled, if possible. Otherwise, the specimen shall be machined from the material as rolled; the axis of the specimen shall be located at any point midway between the center and surface of round bars, or midway between the center and edge of flat bars, and shall be parallel to the axis of the bar.

(*b*) Etch test specimens shall be of the full section of material as rolled.

Number of Tests.

11. (*a*) All bars of one size shall be piled separately. One bar from each 100 or fraction thereof will be selected at random and tested as specified.

(*b*) If any test specimen from the bar originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

IV. PERMISSIBLE VARIATIONS IN GAGE.

Permissible Variations.

12. (*a*) Round bars shall conform to the standard limit gages adopted by the Master Car Builders' Association, now the American Railroad Association, Mechanical Section, as given in Table I.

(*b*) The width or thickness of flat bars shall not vary more than 2 per cent from that specified.

V. FINISH.

Finish.

13. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt.

VI. INSPECTION AND REJECTION.

Inspection.

14. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

15. (*a*) All bars of one size will be rejected if the test specimens representing that size do not conform to the requirements specified.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 12 (*b*) shall be reported within five working days from the receipt of samples.

TABLE I.—STANDARD LIMIT GAGES FOR ENGINE BOLT IRON.

Nominal Diameter of Bars, in.	Large Size, +End, in.	Small Size, −End, in.	Total Variation in.
$\frac{1}{4}$	0.2550	0.2450	0.010
$\frac{5}{16}$	0.3180	0.3070	0.011
$\frac{3}{8}$	0.3810	0.3690	0.012
$\frac{7}{16}$	0.4440	0.4310	0.013
$\frac{1}{2}$	0.5070	0.4930	0.014
$\frac{9}{16}$	0.5700	0.5550	0.015
$\frac{5}{8}$	0.6330	0.6170	0.016
$\frac{3}{4}$	0.7585	0.7415	0.017
$\frac{7}{8}$	0.8840	0.8660	0.018
1	1.0095	0.9905	0.019
$1\frac{1}{8}$	1.1350	1.1150	0.020
$1\frac{1}{4}$	1.2605	1.2395	0.021
$1\frac{3}{8}$	1.3860	1.3640	0.022
$1\frac{1}{2}$	1.5115	1.4885	0.023
$1\frac{5}{8}$	1.6370	1.6130	0.024
$1\frac{3}{4}$	1.7625	1.7375	0.025
$1\frac{7}{8}$	1.8880	1.8620	0.026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

Rehearing.

16. Samples tested in accordance with Section 12 (*b*) which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
HOLLOW STAYBOLT IRON.[1]

Serial Designation: A 86 - 21 T.

These specifications are issued under the fixed designation A 86; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

I. MANUFACTURE.

Process. 1. The iron shall be rolled from a bloom, slab pile or box pile, made wholly from reworked puddled pig iron or reworked knobbled charcoal iron. The puddle mixture and the component parts of the bloom, slab pile or box pile shall be free from any admixture of iron scrap or steel.

Definition of Terms. 2. (*a*) *Bloom.*—A bloom is a solid mass of iron that has been hammered into a convenient size for rolling.

(*b*) *Slab pile.*—A slab pile is built up wholly of flat bars of iron of the full length of the pile.

(*c*) *Box pile.*—A box pile is a pile, the sides, top and bottom of which are formed by four flat bars and the interior of which consists of a number of small bars the full length of the pile.

(*d*) *Iron Scrap.*—This term applies only to foreign or bought scrap and does not include local mill products free from foreign or bought scrap.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition. 3. The iron shall conform to the following requirement as to chemical composition:

Manganese.................................not over 0.10 per cent.

Check Analyses. 4. (*a*) An anlysis may be made by the purchaser from a broken tension test specimen representing each lot as specified in Section 10 (*a*). The chemical composition thus determined shall conform to the requirement specified in Section 3.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. J. B. Young, Secretary of Committee A-2 on Wrought Iron, Philadelphia and Reading Railway Co., Reading, Pa.

(*b*) Drillings for analysis shall be so taken as to represent the entire cross-section of the specimen.

III. PHYSICAL PROPERTIES AND TESTS.

Tension Tests.

5. (*a*) The iron shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	48 000 - 52 000
Yield point, min., lb. per sq. in.	0.6 tens. str.
Elongation, when measured in 8 in., min., per cent...	28
Elongation, " " " 4 " " " ...	35
Reduction of area, min., per cent	42

(*b*) The yield point shall be determined by the drop of the beam of the testing machine. The speed of the cross-head of the machine shall not exceed $\frac{3}{4}$ in. per minute.

Bend Tests.

6. (*a*) The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portion.

(*b*) Bend tests may be made by pressure or by blows.

Splitting Tests.

7. A piece not less than 2 in. long shall be split open from end to end by driving a drift or wedge through the hole. The structure thus exhibited shall be free from signs of imperfect welding and the presence of slag or scale in the welds.

Etch Tests.

8. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. This test shall show the material to have been rolled from a bloom, slab pile or box pile, and to be free from steel.

Test Specimens.

9. All test specimens shall be of the full section of material as rolled.

Number of Tests.

10. (*a*) Bars of one size shall be sorted into lots of 1600 lineal feet. Two samples shall be selected at random from each lot and tested as specified in Sections 5, 6 and 7; but only one of these shall be tested as specified in Sections 4 and 8.

(*b*) If any of the samples originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension test specimen breaks outside the middle third of the gage length, the individual sample shall be rejected and one retest from a different bar or bolt will be allowed.

IV. PERMISSIBLE VARIATIONS IN GAGE.

Permissible Variations.

11. The bars shall be truly round within 0.01 in., and shall not vary more than 0.01 in. above nor more than 0.005 in. below the specified size.

V. FINISH.

Finish. 12. The bars shall be smoothly rolled and free from slivers, depressions, seams, crop ends, and evidences of being burnt.

VI. MARKING.

Marking. 13. The material shall be suitably marked for identification.

VII. INSPECTION AND REJECTION.

Inspection. 14. (*a*) The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. Tests and inspection at the place of manufacture shall be made prior to shipment.

(*b*) The purchaser may make the tests to govern the acceptance or rejection of material in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

(*c*) All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) If either of the samples selected to represent a lot does not conform to the requirements specified in Sections 3, 5, 6, 7, 8 and 9, the lot will be rejected.

(*b*) Unless otherwise specified, any rejection based on tests made in accordance with Section 14 (*b*) shall be reported within five working days from the receipt of samples.

(*c*) Bars which will not take a clean, sharp thread with dies in fair condition, or which develop defects in forging or machining, will be rejected, and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 14 (*b*), which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
CAST-IRON CAR WHEELS.[1]

Serial Designation: A 46 – 21 T.

These specifications are issued under the fixed designation A 46; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

I. MATERIAL.

Material. 1. Wheels shall be made of a mixture of such composition that will produce the required chill in the tread and not show any mottled iron in the plates except around the chaplets where it shall not extend more than ½ in. (12.7 mm.).

II. CHEMICAL REQUIREMENTS.

Chemical Composition. 2. (*a*) The wheels shall conform to the following requirements as to chemical composition:

Combined Carbon	0.50 – 0.85 per cent
Silicon	0.45 – 0.75 per cent
Manganese	0.50 – 0.75 per cent
Phosphorus	not over 0.40 per cent
Sulfur	" " 0.18 per cent

(*b*) The minimum percentage of manganese shall be not less than three times the sulfur content.

(*c*) It is desired that the phosphorus content shall not exceed 0.30 per cent.

Analyses. 3. Drillings for chemical analysis shall be taken from drill hole bored entirely through the back double plate of the wheel between core legs.

III. DIMENSIONS, WEIGHT AND DESIGN OF WHEELS.

Patterns. 4. Patterns and chillers must be such that they will produce wheels according to dimensions shown on drawings furnished by the purchaser.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Cast-Iron Car Wheels. The Standard Specifications, which were last published under the Serial Designation: A 46 – 05, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. G. C. Davies, Secretary of Committee A-3 on Cast Iron, 1410 Real Estate Trust Building, Philadelphia, Pa.

Dimensions. 5. The normal circumference conforming to the specified diameter shall be measured at a point $1\frac{23}{32}$ in. (43.65 mm.) from the gaging point on the throat of the flange. Wheels shall not vary more than $\frac{7}{16}$ in. (11.11 mm.) above or below normal size, measured on the circumference, but only $\frac{5}{16}$ in. (7.94 mm.) variation above or below normal size shall be allowed for any day's cast from one cupola.

The thickness of the flange shall be regulated by a maximum and minimum flange thickness gage which shall be not more than $\frac{1}{16}$ in. (1.59 mm.) over nor more than $\frac{1}{16}$ in. (1.59 mm.) under the normal flange.

Taping. 6. All wheels shall be taped with standard design of wheel circumference tape and have the numbers 1, 2, 3, 4 and 5 stamped $\frac{1}{8}$ in. (3.18 mm.) apart, the figure "3" to represent normal tape size limited by $\frac{1}{16}$ in. (1.59 mm.) over or under the standard circumference, which for 33-in. (838.2-mm.) wheels will be 103.67 in. (2633.2 mm.). The figure "1" shall represent the smallest diameter, and the figure "5" the largest diameter. Tape sizes shall be stenciled in plain figures on the plate of the wheel or otherwise designated, as may be required by the purchaser.

Weights. 7. (*a*) If wheels are ordered in accordance with A.R.A. standard drawings the weight shall be as follows:

MAXIMUM GROSS WEIGHT OF CAR.		NORMAL WEIGHT OF WHEEL.		MINIMUM WEIGHT OF WHEEL.	
LB.	KG.	LB.	KG.	LB.	KG.
95 000	43 000	650	295	640	290
132 000	59 750	700	317	690	313
169 000	76 500	750	340	740	335
210 000	95 250	850	385	840	480

(*b*) In case of wheels ordered with cores smaller in diameter than the standard, the additional weight shall be considered as additional to the normal weight given in the above table and be paid for by the purchaser.

(*c*) In any shipment where the average weight of wheels is above the normal weight given in the above table the excess weight shall be at the expense of the manufacturer.

IV. INSPECTION.

Inspection. 8. Manufacturers shall notify the purchaser when ready to make shipment and shall furnish all necessary facilities and labor to enable the inspector to make test and prompt shipment of wheels.

Surface. 9. The body of the wheel shall be free from slag, shrinkage, or blow holes. The tread and throat shall be free from irregular wrinkles, slag, sand wash, chill cracks or sweat. Wheels will not be rejected on account of cracks around the circumference of the center core commonly known as "drawn hubs" or slight shrinkage holes on the face of the hub which will not interfere with the proper mounting of the wheels.

Marking. 10. All wheels shall be marked and numbered consecutively in accordance with instructions issued by the purchaser. All wheels shall have the initials of purchaser, wheel number, weight of wheel, month, day and year when made plainly cast on the inside plate of the wheel. No wheels shall have duplicate numbers and all indistinct or duplicate numbers may be corrected only after having received the approval of the inspector. All wheels shall have the name of manufacturer and place of manufacture cast on the outside plate of the wheel.

Sampling. 11. When ready for inspection the wheels shall be arranged in groups, all wheels of the same date being grouped together, and for each 102 wheels which pass inspection and are ready for shipment, two representative wheels shall be taken, one of which shall be subjected to the thermal test and the other shall be used for the drop test.

Thermal Test. 12. (*a*) In making the thermal test the wheel shall be laid with the flange downward in the sand and channelway $1\frac{1}{2}$ in. (38 mm.) wide and 4 in. (102 mm.) deep molded in green sand around the wheel, the tread of the wheel to form one side of the channelway and the clean flange forming as much of the bottom as its width will cover. This channelway shall be filled with molten cast iron which shall be hot enough when poured, so that the ring cast, when the metal is cold, will be solid and free from wrinkles. The time when pouring ceases shall be noted and after the time given in Table I has elapsed an examination of the wheel shall be made. If the wheel is broken in two or more pieces or any crack in the plate extends through the rim, all the wheels bearing the same tape size as represented by the sample shall be rejected.

TABLE I.

WEIGHT OF WHEEL.		COOLING TIME, MINUTES.	WEIGHT OF WHEEL.		COOLING TIME, MINUTES.
LB.	KG.		LB.	KG.	
650	295	2	750	340	$2\frac{1}{2}$
700	317	2	850	385	3

(*b*) In order to prevent spitting while pouring, the tread and flange may be covered with a coat of shellac. Wheels selected for test which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances shall the thermal test be applied to a wheel that in any part feels warm to the hand.

Drop Test.

13. (*a*) The anvil of the drop testing machine shall be supported on rubble masonry or a concrete foundation at least 2 ft. (610 mm.) deep and shall weigh not less than 1700 lb. (770 kg.). The striking face of the tup shall be 9 in. (229 mm.) in diameter and flat. The face of each of the three bosses supporting the wheel under test shall be flat and measure 5 in. (127 mm.) in width.

(*b*) The test wheel shall be so placed on the three supports with the flange down, that the tup will strike centrally on the hub. The test wheel shall pass the requirements given in Table II without breaking in two or more pieces. If the test wheel fails, all wheels bearing the same tape size shall be rejected.

TABLE II.

Weight of Wheel.		Weight of Tup.		Height of Drop.		Number of Blows.
LB.	KG.	LB.	KG.	FT.	CM.	
650	295	200	90	9	275	12
700	317	200	90	$10\frac{1}{2}$	320	12
750	340	200	90	12	365	12
850	385	200	90	15	460	12

(*c*) If the test wheel cracks before the twelfth blow it shall be required to stand 15 blows before breaking in two or more pieces.

Chill Test.

14. The wheel selected for drop test shall be broken so that the chill may be examined at at least four different portions of the wheel. The depth of pure white iron shall conform to the following requirements:

Weight of Wheel.		Maximum Depth.				Minimum Depth.			
		At Middle of Tread.		At Throat.		At Middle, of Tread.		At Throat.	
LB.	KG.	IN.	MM.	IN.	MM.	IN.	MM.	IN.	MM.
650	295	1	25.4	$\frac{7}{8}$	22.2	$\frac{1}{2}$	12.7	$\frac{3}{8}$	09.5
700	317	$1\frac{1}{16}$	27.	$\frac{7}{8}$	22.2	$\frac{1}{2}$	12.7	$\frac{7}{16}$	11.1
750	340	$1\frac{1}{8}$	28.6	$\frac{7}{8}$	22.2	$\frac{1}{2}$	12.7	$\frac{1}{2}$	12.7
850	385	$1\frac{1}{8}$	28.6	$\frac{7}{8}$	22.2	$\frac{1}{2}$	12.7	$\frac{1}{2}$	12.7

The depth of the chill shall not vary more than $\frac{1}{4}$ in. (6.35 mm.) in the middle of the tread on the different portions measured. If the sample does not conform to the requirements stated, all wheels of the tape size represented by the sample shall be rejected.

V. RETEST.

Retest.

15. Should the test wheel selected for the drop test, thermal test, or chill test fail to meet the requirements specified, all wheels bearing the same tape size shall be rejected (Sections 12, 13 and

14). The inspector shall then select another wheel of a different tape size, which shall be submitted to the same test as the wheel which failed and if it passes the requirements of the test the remainder of the lot shall be accepted, provided the requirements of all other tests have been met.

VI. REJECTION.

Rejection.

16. The numbers of all wheels which have been rejected because of failure to meet the requirements of the drop test, thermal test, or chill test shall be noted and such wheels shall not be submitted for test at any future time.

Individual Rejection.

17. Individual wheels shall be rejected if they are:

(*a*) Under the minimum weight specified;

(*b*) Have surface defects mentioned in Section 9;

(*c*) Over or under the specified dimensions.

TENTATIVE SPECIFICATIONS

FOR

NON-FERROUS ALLOYS FOR RAILWAY EQUIPMENT IN INGOTS, CASTINGS, AND FINISHED CAR AND TENDER BEARINGS.[1]

Serial Designation: B 17 – 21 T.

These specifications are issued under the fixed designation B 17; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1917; REVISED, 1918, 1921.

Material Covered.

1. (*a*) These specifications cover the various non-ferrous alloys for locomotive equipment in ingots, castings and finished car and tender bearings.

(*b*) These alloys and the purposes for which they are used are as follows:

Phosphor Bronze, for connecting-rod bearings, bushings, eccentric straps, crosshead gibs, and miscellaneous bushings, in place of Bearing Metal No. 1, when specifically covered in the contract.

Bearing Metal No. 1, for connecting-rod bearings, bushings, eccentric straps, crosshead gibs and miscellaneous bushings;

Bearing Metal No. 2, for driving-box bearings, engine-truck and trailer bearings, and hub liners;

Bearing Metal No. 3, for lead-lined bearings, for locomotive tenders, freight and passenger-car equipment;

Bell Metal, for locomotive bells only;

Babbitt Metal, for babbitting driving boxes, rod brasses, crossheads, and for hub liners;

Lining Metal, for lining truck brasses, tender brasses and car brasses.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., Bayonne, N. J.

I. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

2. (*a*) The alloys shall conform to the following requirements as to chemical composition, with the permissible variations specified:

Alloy.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, max., per cent.	Iron max., per cent.	Antimony, per cent.	Phosphorus, max., per cent.	Sulfur max, per cent.	Arsenic, max., per cent.	Total Impurities, including Zinc, max., per cent.
Phosphor Bronze......	remainder	9-11	8-11	0.75	0.25	0.25[a]	0.7-1.0	....	....	1.0
Bearing Metal No. 1.......	remainder	9-11	9-11	1.50	0.25	0.25[a]	....	....	....	2.0
Bearing Metal No. 2.......	remainder	4-6	22.5-26.5	0.75	0.40	0.50[a]	....	....	....	1.5
Bearing Metal No. 3........	remainder	4-6	17-22	2.50	0.40	0.50[a]	....	....	....	3.0
Bell Metal.....	remainder	16-18	0.25[a]	0.25	0.25	0.25[a]	0.02[a]	0.05	....	0.50
Babbitt Metal	0.50[a]	9.25-10.75	remainder	none	....	14-16	....	....	0.20	0.75[b]
Lining Metal..	0.50[a]	4.50-5.50	remainder	none	...	9.25-10.75	....	....	0.20	0.75[b]

[a] Maximum.
[b] Must not contain zinc.

(*b*) Where no figures are given for impurity maximum, these elements may be present up to any amount to come within the total impurity specified, provided the material otherwise meets the chemical and physical tests. Where maximum percentages are specified, the elements referred to are considered as impurities and shall not be intentionally added.

Chemical Analysis.

3. An analysis will be made by the purchaser or his representative from one ingot, casting or journal bearing representing each lot. The chemical composition thus determined shall conform to the requirements specified in Section 2 for the particular alloy.

Sample for Chemical Analysis.

4. (*a*) *Ingots.*—Drillings shall be taken with a drill at least ½ in. in diameter at a point midway between the heaviest and smallest cross-section of the ingot. For ingots having two or more sections, drillings shall be taken from each section. In the case of Babbitt Metal and Lining Metal, drillings so taken shall be melted in a thoroughly cleaned ladle with a little rosin flux and poured into a piece of thin section. This piece shall be sawed into three parts and the sawings therefrom thoroughly mixed to constitute the sample for chemical analysis.

(*b*) *Locomotive Castings.*—Drillings shall be taken with a drill as large as possible at such points in the casting as shall be thoroughly representative. Drillings through the skin shall be rejected. Drillings thoroughly mixed shall constitute the sample for chemical analysis.

(*c*) *Car and Tender Bearings.*—Drillings shall be taken with a drill at least ½ in. in diameter, at three points as widely separated as possible on the bearing selected for physical test as specified in Section 5 (*b*). Drillings representing the skin of the casting shall be rejected. These drillings, thoroughly mixed, shall constitute the sample for chemical analysis.

Drillings shall be taken in a like manner from the lining, exercising care that the drill does not penetrate the soldered surface.

(*d*) All samples, whether taken with a drill or saw, shall be kept free of oil and shall be carefully treated with a magnet to remove any iron introduced in taking the sample.

II. PHYSICAL INSPECTION AND TESTS.

Physical Inspection

5. (*a*) *Locomotive Castings.*—The castings shall be sound, free from blowholes, flaws or shrinkage cracks, and shall show good foundry practice and workmanship.

One casting representing each lot of locomotive bearings will be broken by the purchaser or his representative for examination of fracture. The fracture shall disclose no shrink discoloration, segregation, dross or dirt spots within ⅝ in. of the bored journal engaging surface, and shall show no distinct signs of imperfect mixture.

(*b*) *Car and Tender Bearings.*—The bearings shall be sound, free from sand, blowholes, flaws or shrinkage cracks, and shall show good foundry practice and workmanship.

One bearing representing each lot will be broken by the purchaser or his representative for examination of fracture. The fracture shall show no shrink discoloration, segregation, dross or dirt spots within ½ in. of the bored journal engaging surface. This test shall be made before linings are applied. A second test shall be made after application of the lining as follows:

(1) The suspended brass when tapped with a hammer shall give a distinct ring.

(2) The lining when chipped with a cold chisel shall tear from the soldered surface as distinguished from clean shearing.

III. LOT.

Lot.

6. (*a*) *Ingots.*—Each 5000 lb. or fraction thereof shall constitute a lot. The ingot from which the sample is taken shall be included in the shipment.

(*b*) *Locomotive Castings.*—Unless otherwise specified, each 100 castings or fraction thereof shall constitute a lot.

The manufacturer shall furnish, free of cost, one casting representing each lot for purpose of tests as specified in Sections 4 (*b*) and 5 (*a*).

(*c*) *Car and Tender Bearings.*—Unless otherwise specified, each 300 bearings or fraction thereof from each pattern shall constitute a lot.

The manufacturer shall furnish, free of cost, one bearing representing each lot for purpose of tests as specified in Sections 4 (*c*) and 5 (*b*).

IV. PERMISSIBLE VARIATIONS IN DIMENSIONS.

(FOR CAR AND TENDER BEARINGS ONLY.)

Permissible Variations.

7. (*a*) The purchaser will furnish drawings showing the dimensions of the bearings ordered and permissible variations therefrom, and the bearings shall conform to these drawings within such permissible variations.

(*b*) The thickness at the center of the brass and of the complete bearing shall not vary more than $\frac{1}{32}$ in. over or under the normal thickness shown on the drawing. The thickness of the lining shall not vary more than $\frac{1}{32}$ in. over or under the normal thickness shown on the drawing.

V. WORKMANSHIP.

Workmanship.

8. (*a*) *Locomotive Castings.*—The castings shall conform to the dimensions specified and shall show good workmanship generally.

(*b*) *Car and Tender Bearings.*—The bearings shall show good workmanship generally, and shall be free from mechanical imperfections. They shall be bored to a true radius, and with the axis parallel to the plane of the top and perpendicular to the side lugs and bearing flange. The lettering shall be clear and distinct. No emery shall be used on journal engaging surfaces on either the brass or the lining.

VI. MARKING.

Marking. 9. (*a*) *Ingot.*—The manufacturer's marking only shall be required, unless otherwise specified.

(*b*) *Locomotive Castings.*—The lot number and other marks as required by the drawings shall be legibly marked on each casting.

(*c*) *Car and Tender Bearings.*—The name or initials of the manufacturer, the initials of the purchaser, type number, journal size, and lot number shall be legibly cast with raised figures on a depressed surface of each bearing, as shown on the drawings.

VII. INSPECTION AND REJECTION.

Inspection. 10. (*a*) Inspection may be made at the manufacturer's works where the ingots, locomotive castings or car and tender bearings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 11. Failure to meet the chemical or physical specifications, or non-conformity to any of the above requirements as to permissible variations, dimensions and markings, constitute sufficient cause for rejection of the lot represented by the sample chosen.

TENTATIVE SPECIFICATIONS

FOR

BRASS INGOT METAL, GRADED AND UNGRADED FOR SAND CASTINGS.[1]

Serial Designation: B 30 - 21 T.

These specifications are issued under the fixed designation B 30; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1919; REVISED 1921

Material Covered.

1. These specifications cover brass ingot metal for sand castings, known commercially as red and yellow brass ingot, made wholly or partly from scrap materials. Seven typical alloys are specified and are designated Grades Nos. 1 to 7, in accordance with their decreasing copper content as specified in Section 3. These specifications also cover brass ingot metal which has no grade limit, designated as ungraded material such as a specific lot of ingots having a stated composition suitable for the buyers' needs.

I. MANUFACTURE.

Uniform Quality.

2. The manufacturer shall use care to have each lot of ingot metal as uniform in quality as possible. Individual ingots of any lot shall not show an extreme variation between the high and low copper percentages of more than 2.5 per cent and between the high and low percentages of the other main constituents, except zinc, of more than 1.5 per cent.

II. CHEMICAL PROPERTIES AND TESTS.

Chemical Composition.

3. The graded alloys shall conform to the following requirements as to chemical composition, within the limits specified in Section 4:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., Bayonne, N. J.

Alloy, Grade No.	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, per cent.	Iron, max., per cent.	Antimony, max., per cent.	Aluminum, per cent.	Sulfur, max., per cent.
1.........	87	8	2[a]	3	0.25	0.25	none	0.05
2.........	85	5	5	5	0.35	0.25	none	0.05
3.........	83	4	6	7	0.35	0.25	none	0.05
4.........	77	3	10	10	0.40	0.35	none	0.05
5.........	76	2	6	16	0.40	0.25	none	0.05
6.........	65	1[a]	2	33	0.50	0.20	none[1]	0.05
7.........	60	1½[a]	3	37	1.00	0.20	none[1]	0.05

[a] Maximum. [1] See Appendix.

Permissible Variations.

4. The following permissible variations in the percentages of the desired elements specified in Section 3 will be allowed, but shall not apply to the maximum percentages of impurities specified:

PERCENTAGE OF ELEMENT SPECIFIED.	PERMISSIBLE VARIATIONS OVER AND UNDER THE SPECIFIED VALUE, UNITS OF PER CENT.
Not over 5 per cent..........................	0.50
Over 5 to 15 per cent, incl..........................	0.75
Over 15 per cent..........................	1.00

Samples for Chemical Analysis.

5. (*a*) Ten ingots shall be selected by the inspector to represent 40,000 lb. and five ingots for less than carload lots.

(*b*) The samples for chemical analysis may be taken either by sawing, drilling or milling the ingots and shall represent the average cross-section.

(*c*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

Methods of Chemical Analysis.

6. To be prepared by the Committee.

III. MARKING.

Marking.

7. The designating mark of the manufacturer, the proper lot number, and the numerical designation of the grade supplied shall be marked on each ingot for identification.

IV. INSPECTION AND REJECTION.

Inspection.

8. (*a*) Inspection may be made at the manufacturer's works where the ingots are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, free of cost, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

9. If the test ingots selected to represent a lot fail to conform to the requirements specified in Sections 3 and 4, all ingots in such lot will be rejected.

V. CLAIMS.

Claims.

10. Claims, to be considered, shall be made in writing within thirty days of receipt of material at the purchaser's plant, and the results of the purchaser's tests shall be given. The shipper shall within one week of receipt of such claim, either agree to satisfy the claim or send a representative to the purchaser's plant to resample the shipment, as specified in Section 5. Samples so taken shall be sealed and submitted to a mutually agreeable umpire, whose determination shall be final.

Settlement of Claims.

11. The expense of umpire analysis shall be paid by the loser or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of ingot metal meeting these specifications.

APPENDIX.

The data in the following table do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified which can be expected of carefully manufactured alloys of the formulas indicated, and to constitute a guide to the purchaser in selecting the grade best suited for meeting the service condition for which the ingot metal is to be used.

TABLE SHOWING PHYSICAL PROPERTIES OF BRASS INGOT METAL ALLOYS.

Alloy, Grade No.	DESIRED COMPOSITION.				Tensile Strength, lb. per sq. in.[1]	Elongation, in 2 in., per cent.[1]	Reduction of Area, per cent.[1]	Brinell Hardness (500 kg. for 30 sec.).	Shrinkage, in. per ft.	Weight, lb. per cu. in.
	Copper, per cent.	Tin, per cent.	Lead, per cent.	Zinc, per cent.						
1	87	8	2	3	30-36 000	25-30	25-30	.....	0.125	0.31
2	85	5	5	5	27-33 000	16-20	15-20	50-60	0.14	0.31
3	83	4	6	7	28-33 000	15-20	20-26	55-60	0.125	0.31
4	77	3	10	10	23-28 000	10-15	10-15	50-55	0.125	0.32
5	76	2	6	16	25-30 000	20-30	20-30	43-48	0.18	0.31
6	65	...	2	33	25-30 000	20-30	25-35	37-42	0.18	0.30
7	60	...	3	37	30-45 000	15-25	20-30	43-48	0.20	0.29

[1] The tension tests were made on "sand cast-to-size" test specimens.

Grade No.	Example of Uses.	Foundry Manipulation.	Characteristics.
1	High grade steam metal	Easily handled	Machines well.
2	High grade red brass for general service	Easily handled	Machines more readily than No 1.
3	Medium grade red brass for general service	Easily handled	Machines more readily than No. 1.
4	Valves and fittings for low pressures	Not difficult	Machines very easily.
5	Reddish yellow alloy, for air, gas and water fittings.	Not difficult	Machines very easily.
6	Yellow brass for general service	Difficult. Aluminum up to 0.3 per cent improves casting properties, but increases shrinkage.	Machines poorly. Not suitable for bearings or water pressure fittings.
7	Plumbers' flanges, scupper pipes, etc	Very difficult. Aluminum up to 0.3 per cent improves casting properties, but increases shrinkage.	Hard to machine. Not suitable for bearings or water pressure fittings.

TENTATIVE SPECIFICATIONS
FOR
NICKEL.[1]

Serial Designation: B 39 – 21 T.

These specifications are issued under the fixed designation B 39; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered.

1. (*a*) These specifications cover four grades of Virgin Nickel, *i. e.* nickel made from ore or matte, or similar raw material by refining processes, and not produced from remelted metal, as follows:

Electrolytic;
"X" Shot;
"A" Shot;
Ingot.

(*b*) The uses for which these four grades of Virgin Nickel are intended to be especially suitable are as follows:

Electrolytic, suitable for the manufacture of the highest grades of malleable alloys.

"X" Shot, suitable for the manufacture of Non-Ferrous Alloys and Nickel Steel.

"A" Shot, suitable for the manufacture of anodes.

Ingot, suitable for the manufacture of open-hearth and electric-furnace Nickel Steel.

I. MANUFACTURE.

Quality.

2. The maker shall use care to have each carload of as uniform quality as possible.

II. CHEMICAL REQUIREMENTS AND TESTS.

Chemical Composition

3. The nickel shall conform to the following chemical requirements:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., Bayonne, N. J.

(*a*) *Electrolytic:*

Nickel (including cobalt)	not less than	99.50	per cent
Sulfur	" over	0.02	"
Carbon	" "	0.10	"
Iron	" "	0.25	"

(*b*) *"X" Shot:*

Nickel (including cobalt)	not less than	98.90	per cent
Sulfur	not over	0.05	"
Carbon	" "	0.25	"
Iron	" "	0.60	"

(*c*) *"A" Shot:*

Nickel (including cobalt)	not less than	97.75	per cent
Sulfur	not over	0.070	"
Carbon	" "	0.75	"
Iron	" "	0.90	"

(*d*) *Ingot:*

Nickel (including cobalt)	not less than	98.50	per cent

It shall be reasonably free from surface corrosion and adhering foreign matter.

Sampling. 4. (*a*) *Electrolytic.*—In all shipments cathodes shall be taken representing five per cent of the total weight shipped, but in no case shall the number of cathodes taken as samples be less than three.

The cathodes taken as samples shall be drilled by templet. In the case of a shipment represented by a sufficient number of cathodes, one line of holes on the templet shall be used for each cathode, *i. e.*, cathode No. 1 shall be drilled at the base, cathode No. 2 shall be drilled with one line of holes further up, etc., the resultant sample being a representation of the total sample of one whole cathode. In cases where the cathodes in the sample are less than the number of lines of holes in the templet, the sample shall be drilled using sufficient lines and fractions thereof to insure at all times a sample representative of one whole cathode. In all cases the drilling shall be done through the cathodes. The drillings obtained in the above manner shall be thoroughly mixed and divided by split sampler until the sample is about 100 g.

(*b*) *"X" Shot.*—In receiving shipments of shot, the following method of sampling shall govern: All barrels from the same melt shall be opened and a sample taken from each barrel, top, center and bottom. These barrel samples shall be mixed, quartered down to 8 oz. and broken into small pieces. This broken sample shall then be quartered down to 100 g., only material passing through a 20-mesh screen being used.

(*c*) "*A*" *Shot.*—The sample shall be taken as described in Paragraph (*b*).

(*d*) *Ingot.*—Ingot nickel shall be sampled according to carloads whenever possible. From each carload fifty ingots shall be taken at random. In case of less than carload shipments, 5 per cent of the ingots shall be taken as a sample, but in no case shall the number of ingots taken as a sample be less than ten.

The ingots taken as samples shall be drilled by templet. In the case of a shipment represented by a sufficient number of ingots, one line of holes on the templet shall be used for each ingot, *i.e.*, ingot No. 1 shall be drilled at the base, ingot No. 2 shall be drilled with one line of holes further up, etc., the resultant sample being a tepresentation of the total sample of one whole ingot. In cases where the ingots in the sample are less than the number of lines of holes in rhe templet, the sample shall be drilled using sufficient lines and fractions thereof to insure at all times a sample representative of one whole ingot. In all cases, the drilling shall be done through the ingots. The drillings obtained in the above manner shall be thoroughly mixed and divided by split sampler until the sample is about 100 g.

Methods of Analysis.

5. The chemical analysis shall be made in accordance with the Tentative Methods of Chemical Analysis of Nickel (Serial Designation: B 41 - 21 T), of the American Society for Testing Materials.[1]

III. PACKAGES.

Packages.

6. All packages and barrels shall be marked with a brand by which the maker and grade can be identified.

IV. CLAIMS.

Claims.

7. Claims in writing only shall be considered and must be submitted within 30 days of receipt of material at purchaser's plant, and with each claim shall be submitted the results of purchaser's tests. The seller shall be given one week from date of receipt of such claim to investigate his records and shall then agree either to satisfy the claim or to send a representative to the purchaser's mill.

(*a*) *Chemical Defects.*—No claims shall be considered unless the purchaser can submit to seller's representative the minimum sample of the grade specified in question.

(*b*) *Physical Defects.*—No claims shall be considered unless the purchaser can submit unused samples of the material in question to seller's representative.

Plant Treatment.

8. Where the material satisfied the chemical and physical requirements of these specifications, it shall not be condemned for defects of alloys in which it is used.

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[1] See p. 522.

Investigation of Claims.

9. The maker's representative shall inspect all pieces where the physical defects are claimed. If agreement is not reached the question of fact shall be submitted to a mutually agreeable umpire, whose decision shall be final.

On a question of metal contents a sample shall be taken by representatives of both parties as described under that paragraph of Section 4 applicable to the material in question. The properly mixed sample shall be separated into three parts, each of which shall be placed in a sealed package, one for each party and one for an umpire, if necessary. Each party shall make analysis, as specified in Section 5, and if the results do not establish or dismiss the claim to the satisfaction of both parties, the third sample shall be submitted to a mutually agreeable umpire, who shall determine the question of quality, and whose determination shall be final.

Settlement of Claims.

10. The expenses of the seller's representative and of the umpire shall be paid by the loser or divided in proportion to concession made in case of compromise.

In case of rejection being established, damages shall be limited to payment of freight both ways by the seller and substitution of an equivalent weight of nickel meeting specifications for the grade in question.

TENTATIVE METHODS OF CHEMICAL ANALYSIS OF ALUMINUM AND LIGHT ALUMINUM ALLOYS.[1]

Serial Designation: B 40 - 21 T.

These methods are issued under the fixed designation B 40 ; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

The methods of analysis listed under "Analysis of Aluminum" contemplate the analysis of aluminum containing more than 98 per cent aluminum and containing only silicon, titanium, iron, copper, carbon and traces of manganese as impurities.

Unless it is positively known that such elements as tin, antimony, zinc, lead, nickel, magnesium, sodium, nitrogen or oxygen (as aluminum oxide) are absent, the methods listed under the "Analysis of Light Aluminum Alloys" should be employed.

ANALYSIS OF ALUMINUM.

(NOT LESS THAN 98 PER CENT ALUMINUM.)

A. DETERMINATION OF NON-GRAPHITIC SILICON, GRAPHITIC SILICON, TOTAL SILICON, TITANIUM AND IRON.

DETERMINATION OF NON-GRAPHITIC SILICON.

SOLUTIONS REQUIRED.

"*Acid Mixture*."—1200 cc. of H_2SO_4 (25-per-cent by volume), 600 cc. HCl (sp. gr. 1.20) and 200 cc. HNO_3 (sp. gr. 1.42).

25-per-cent Sulphuric Acid.—Pour 250 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, and dilute to 1000 cc.

METHOD.

Dissolve 1 g. of the well-mixed sample in 35 cc. of the acid mixture in a covered flat-bottomed porcelain dish or casserole. When the drillings are completely dissolved, boil the solution to complete expulsion of HNO_3 and HCl and heat until copious fumes of H_2SO_4 have been given off for five minutes. Cool and take up the residue with 10 cc. of 25-per-cent H_2SO_4 and 100 cc. of water. Warm to complete solution of the sulfates and filter on an ashless filter paper. Wash the residue with hot water until free from sulfates, ignite in a platinum crucible and weigh. Treat the ash with HF and a few drops of 25-per-cent H_2SO_4, carefully evaporate, ignite and again weigh. The difference in the two weights multiplied by the factor 46.93 represents the percentage of non-graphitic silicon.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, International Nickel Co., Bayonne, N. J.

DETERMINATION OF GRAPHITIC SILICON.

See "Determination of Non-Graphitic Silicon."

The non-volatile residue obtained above, especially if dark colored, may contain graphitic silicon. Treat the non-volatile residue with 5 cc. HNO_3, 5 cc. HF, carefully evaporate, and add 2 or 3 drops of 25-per-cent H_2SO_4 toward the end of the evaporation. Ignite and weigh. Reserve the residue for the "Determination of Titanium." The loss in weight multiplied by 100 represents the percentage of graphitic silicon.

DETERMINATION OF TOTAL SILICON.

The total silicon is represented by the sum of the percentages of non-graphitic and graphitic silicon.

NOTES.

Blanks should be carried along with all reagents and the proper corrections made.

Graphitic silicon is not oxidized to silica by the solution or ignition treatments and therefore resists the action of HF and H_2SO_4. Graphitic silicon is, however, readily attacked and volatilized by a mixture of HNO_3 and HF.

DETERMINATION OF TITANIUM.

APPARATUS AND SOLUTIONS REQUIRED.

Nessler tubes or some form of colorimeter.

Hydrogen Peroxide U. S. P.—This reagent must be free from HF.

Standard Titanium Solution.—This solution is best prepared and standardized as follows:[1]

"Potassium titanium fluoride, K_2TiF_6, best serves as the starting point for the preparation of the standard solution. A quantity of this is recrystallized from boiling water one or more times, dried, and preserved in a glass-stoppered bottle. Enough of it to make 0.5 to 1 liter of the standard sulfate solution is put into a platinum dish and evaporated several times with strong sulfuric acid without bringing to dryness, till the fluorine is completely expelled. The residue is then taken up with water containing enough sulfuric acid to make at least 5 per cent of the latter when fully diluted. Two 50 to 100-cc. portions of the prepared solution are then further diluted, boiled, and precipitated with ammonia. The precipitates are collected on paper, washed with hot water till free from alkali, ignited moist in the filter, blasted, and weighed. Duplicates should agree almost exactly. From the weights found, the strength of the standard is calculated and the result affixed to the bottle containing it. The stopper of the bottle should be coated with vaseline and the needed quantities of solution should be withdrawn by a pipette, never poured. In a solution so prepared there is not enough alkali sulfate to weaken the color when peroxidized."

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[1] W. F. Hillebrand, "The Analysis of Silicate and Carbonate Rocks," *Bulletin No. 700*, U. S. Geological Survey, p. 157.

METHOD.

See "Determination of Graphitic Silicon".

Fuse the non-volatile residue remaining after the graphitic silicon determination in a small amount of $K_2S_2O_7$, take up in a little 5-per-cent H_2SO_4 and add to the filtrate and washings from the silicon determination. Evaporate the solution to approximately 100 cc., and treat with 5 cc. H_2SO_4 (sp. gr. 1.84) and 3 g. of iron-free zinc. Heat until the zinc is nearly dissolved and the reduction of copper is complete. Decant the solution into another beaker, wash the zinc and copper with hot water and continue the evaporation of the solution to approximately 75 cc. Cool and transfer to a 100-cc. Nessler's comparison tube, add 5 cc. of 3-per-cent H_2O_2 and dilute to the 100-cc. mark. In another tube, place 88 cc. H_2O, 5 cc. of H_2SO_4 (sp. gr. 1.84) and cool. Add 5 cc. of 3-per-cent H_2O_2 and then from a burette add the standard titanium solution until the colors match. Reserve the tested solution for the determination of iron. The volume of the standard solution required multiplied by 100 times its titre represents the percentage of titanium in the sample.

NOTES.

The filtrate and washings from the Silicon Determination should ordinarily be colorless. If light yellow owing to iron, the standard comparison solution should be brought to the same tint with ferric sulfate solution before adding the hydrogen peroxide.

In case the amount of titanium is high the solution may be diluted to a definite volume and aliquot portions taken for the colorimetric test.

DETERMINATION OF IRON.

SOLUTIONS REQUIRED.

Potassium Permanganate Solution (10-per-cent).—Dissolve 10 g. of $KMnO_4$ in distilled water and dilute to 100 cc.

Dilute Sulfuric Acid for Reduction.—Mix 50 cc. of H_2SO_4 (sp. gr. 1.84) and 1000 cc. of distilled water. This solution is used boiling hot.

Standard Potassium Permanganate Solution.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. H_2O, and allow to stand for several days in a glass-stoppered bottle in a dark closet. Filter the solution through prepared asbestos and standardize against 0.1000-g. portions of pure sodium oxalate. Each cubic centimeter is equivalent to approximately 0.0018 g. of iron.

METHOD.

See "Determination of Titanium."

Transfer the solution used in the "Determination of Titanium" from the Nessler tube to a 400-cc. beaker, add 10-per-cent $KMnO_4$ solution to a good permanent pink tint and pass the solution through the reductor. Wash the beaker and reductor with 150 cc. of the H_2SO_4 for reduction and then with 100 cc. of distilled water. Titrate with the standard $KMnO_4$ solution.

The results of the titration should be corrected by a "blank" determination made on 100 cc. of a 7-per-cent H_2SO_4 solution which has been carried through as in the titanium and iron determinations, not omitting the treatment with iron-free zinc, hydrogen peroxide, and permanganate preliminary to the actual reduction. About 0.5 cc. of the permanganate solution will be required to give a permanent color to the blank.

Calculate the apparent percentage of iron. To obtain the true percentage, multiply the percentage of titanium by 1.161 and subtract.

NOTES.

For description and further details of use of reductor see "Chemical Analysis of Iron," by A. A. Blair, or "Quantitative Chemical Analysis," by H. P. Talbot.

Air should never be allowed to enter the body of the reductor.

Titanium is reduced to the trivalent condition in the reduction process and afterwards oxidized to the quadrivalent condition by the permanganate. There is a slight tendency toward oxidation in the receiver, but this may be disregarded in the small amounts of titanium ordinarily involved.

In case titanium is present and iron alone is to be determined proceed as follows: Place the H_2SO_4 solution of the sample in a 250-cc. flask, dilute to 100 cc. containing 2.5 cc. H_2SO_4 (sp. gr. 1.84) and treat with H_2S for 30 minutes in the cold and 15 minutes while warmed. If sulfides appear, filter and gas the filtrate 10 minutes more.

Add 15 cc. H_2SO_4 (1 : 1) and boil vigorously until H_2S is expelled and the volume reduced to 50 cc. Fill the flask with distilled water, transfer to a beaker, and titrate with $KMnO_4$ solution.

DETERMINATION OF COPPER.

(*a*) *Electrolytic Method.*

APPARATUS FOR ELECTROLYSIS.

See the "Determination of Copper by the Electrolytic Method" in the Standard Methods of Chemical Analysis of Manganese Bronze (Serial Designation : B 27) of the American Society for Testing Materials.[1]

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (*1 : 1*).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool and dilute to 1000 cc.

METHOD.

Dissolve 10 g. of the sample in 100 cc. of dilute H_2SO_4 (1 : 1). When action has ceased add 25 cc. of HNO_3 (sp. gr. 1.42) and boil until oxides of nitrogen have been expelled. Filter into the tall form of beaker used in electrolysis and wash the residue with hot water. Dilute to 400 cc. and electrolyze. Use a weighed sand-blasted cathode and a current of from 3 to 5 amperes at approximately 10 volts. When the solution is colorless and 1 cc. of the solution gives no copper test with H_2S water on a porcelain plate, remove the solution from the electrodes quickly without interrupting the current. Quickly rinse the cathode in distilled water and then dip it in two successive baths of alcohol. Shake off the excess alcohol and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

NOTES.

The electrolytic method is preferred for the determination of copper no matter what the percentage.

It is not anticipated that the aluminum will contain tin. In case tin has been found it will be preferable to precipitate with hydrogen sulfide as in the optional method. The sulfides are then to be dissolved, digested in HNO_3 (1 : 1), the metastannic acid filtered off and the electrolysis then carried out.

A staining of the anode indicates the presence of lead or manganese.

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[1] 1921 Book of **A.S.T.M. Standards.**

(*b*) *Iodide Method.* (Optional.)

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1:1).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool and dilute to 1000 cc.

Wash Solution.—Saturate 500 cc. of H_2SO_4 (1 : 99), with H_2S.

Nitric Acid (1 : 1).—Pour 500 cc. of HNO_3 (sp. gr. 1.42) into distilled water, cool and dilute to 1000 cc.

Potassium Iodide Solution.—Dissolve 30 g. of KI in water and dilute to 100 cc.

Sodium Thiosulfate Solution.—Dissolve 19 g. of $Na_2S_2O_3.5H_2O$ in distilled water and dilute to one liter. After aging for 1 week or more in a glass-stoppered bottle, standardize against 0.1 g. portions of C.P. copper or suitable material of known copper content, carried through the operations of the method described below. One cubic centimeter should correspond to approximately 0.005 g. of copper.

Starch Solution.—Grind 0.5 g. arrow-root starch in a mortar with a little water to a smooth paste and pour into 250 cc. of boiling water. Boil 3 minutes, cool, and allow to settle. The clear solution should be employed and it must be prepared frequently.

METHOD.

Place 10 g. of the sample in a covered porcelain dish or casserole and dissolve in 80 cc. of dilute H_2SO_4 (1 : 1). When solution is complete, add 5 cc. of HNO_3 (sp. gr. 1.42) and evaporate the solution until dense fumes of H_2SO_4 are given off. Cool the solution and add 200 cc. of distilled water. Boil until the sulfates are in solution, filter and wash with hot water. Treat with hydrogen sulfide until the solution is cold. Filter, wash with the hydrogen sulfide wash solution and dissolve the precipitate in the smallest possible amount of hot HNO_3 (1 : 1). Digest the HNO_3 solution at near boiling for one hour unless the absence of tin is assured. Filter if necessary and evaporate to a syrupy consistency. Transfer the HNO_3 solution of the copper to a 250-cc. flask add 5 cc. of strong bromine water and boil until all bromine and oxides of nitrogen are expelled. Add a slight excess of NH_4OH, add then $HC_2H_3O_2$ in slight excess. Cool, add 10 cc. of KI solution and titrate at once with the $Na_2S_2O_3$ solution until the free iodine is nearly removed, then add 5 cc. of starch solution and continue the titration cautiously until the color due to free iodine has entirely vanished. The volume of thiosulfate employed multiplied by ten times its copper titre represents the percentage of copper in the sample.

NOTE.

Copper, when present in small amounts, may also be determined by potassium cyanide titration. See Standard Methods of Chemical Analysis of Alloys of Lead, Tin, Antimony and Copper (Serial Designation: B 18) of the American Society for Testing Materials.[1]

DETERMINATION OF MANGANESE.

(*a*) *Persulfate Method.* (For samples containing under 1.5 per cent of Manganese.)

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1 : 1).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool, and dilute to 1000 cc.

Silver Nitrate.—Dissolve 1.33 g. of $AgNO_3$ in 1000 cc. of distilled water.

Stock Sodium Arsenite Solution.—To 15 g. of arsenious oxide (As_2O_3) in a 300-cc. Erlenmeyer flask, add 45 g. of Na_2CO_3 and 150 cc. of distilled water. Heat the flask and contents on the steam bath until the As_2O_3 is dissolved. Cool the solution, filter and make up to 1000 cc. with distilled water.

Standard Sodium Arsenite Solution.—Mix 200 cc. of the stock sodium arsenite solution with 2500 cc. of distilled water, and standardize by the method described below against a steel or iron of known manganese content. One cubic centimeter of this solution should be equivalent to approximately 0.00050 g. of manganese.

Ammonium Persulfate.—Dissolve 6 g. of ammonium persulfate in 100 cc. of distilled water. (This solution should be made up as needed as it deteriorates rapidly.)

METHOD.

In a 250-cc. Erlenmeyer flask, dissolve 0.5 g. of the sample in 25 cc. of H_2SO_4 (1 : 1) by warming and adding a drop or two of HNO_3 (sp. gr. 1.42) occasionally until solution is complete. Boil until oxides of nitrogen are expelled. Dilute with hot water to 200 cc. When the solution is boiling add 20 cc. of $AgNO_3$ solution and 30 cc. of the persulfate solution. Boil not less than one minute nor more than 2 minutes. (Instead of boiling, the solution may be left on the steam bath until it has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion.) Cool to below 25° C. in running water, and add 50 cc. of cold water. Titrate with the standard arsenite solution to the disappearance of the pink color.

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[1] 1921 Book of A.S.T.M. Standards.

NOTE.

Large amounts (above 0.01 g. of manganese per 100 cc. of solution) of permanganic acid are unstable; the method can, however, be used with satisfaction for alloys containing high percentages of manganese by decreasing the size of the sample.

(*b*) *Bismuthate Method.* (For samples containing less than 1.50 per cent manganese.) (Optional.)

SOLUTIONS REQUIRED.

Dilute Sulfuric Acid (1 : 1).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool and dilute to 1000 cc.

Nitric Acid (1 : 3).—Pour 250 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 1000 cc.

Dilute Nitric Acid (3-per-cent).—Pour 30 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 1000 cc.

Standard Permanganate Solution.—Dissolve 1 g. of $KMnO_4$ in 1000 cc. of distilled water. Allow it to stand for at least one week and then filter through purified asbestos. Standardize against 0.1 g. portions of pure sodium oxalate. One cubic centimeter of this solution should be equal to approximately 0.00035 g. of manganese.

Standard Ferrous Ammonium Sulfate Solution.—Dissolve 12.4 g. of ferrous ammonium sulfate crystals in 950 cc. distilled water, and add 50 cc. of H_2SO_4 (sp. gr. 1.84).

METHOD.

In a 250-cc. Erlenmeyer flask dissolve 0.5 g. of the sample in 10 cc. of H_2SO_4 (1 : 1), adding a drop or two of HNO_3 (sp. gr. 1.42) occasionally.

When solution is complete heat to expel all oxides of nitrogen and cool. Dilute with 50 cc. of HNO_3 (1 : 3) and add 0.5 g. sodium bismuthate. Heat for a few minutes until the purple color has disappeared with or without the precipitation of manganese dioxide. Add a little ferrous ammonium sulfate solution until the solution becomes clear and boil until the oxides of nitrogen are expelled. Cool, add an excess of sodium bismuthate and agitate for a few minutes. Add 50 cc. of 3-per-cent HNO_3 and filter through an alundum crucible or an asbestos pad. Wash with 50 cc. of 3-per-cent HNO_3. Add from a pipette or a burette 10 to 50 cc. (depending on the amount of permanganic acid) of ferrous ammonium sulfate solution and titrate with the $KMnO_4$ solution.

In exactly the same manner carry through a blank determination using the same amounts of H_2SO_4, HNO_3, and sodium bismuthate as was done with the regular sample. Finally add the exact volume of ferrous ammonium sulfate solution employed and titrate with the $KMnO_4$ solution.

The difference between the volumes required in the two titrations represents the manganese in the sample, and the percentage is found by multiplying this volume by 200 times the manganese titre of the permanganate solution.

NOTES.

Large amounts (above 0.01 g. of manganese per 100 cc. of solution) of permanganic acid are unstable; the method can be used with satisfaction for alloys containing high percentages of manganese by decreasing the size of the sample.

The filtrate from the bismuthate must be perfectly clear, as the least particle of bismuthate carried into the filtrate will vitiate the results.

The solution must be cold at time of filtration and titration.

Instead of employing the method of reducing permanganic acid by means of standardized ferrous ammonium sulfate solution and titrating the excess of the reagent, it is possible to reduce the permanganic acid by standard sodium-arsenite solution. See "Determination of Manganese by the Persulfate Method."

DETERMINATION OF CARBON.

SOLUTIONS REQUIRED.

Copper-Potassium Chloride Solution.—Dissolve 300 g. of $CuCl_2.2KCl.2H_2O$ in water, dilute to 1000 cc., filter through ignited asbestos and preserve in a glass-stoppered bottle.

METHOD.

Place 3 g. of the sample in a 400-cc. beaker, add 200 cc. of the $CuCl_2.2KCl$ solution and 10 cc. of HCl (sp. gr. 1.20). Stir the solution constantly with a glass rod for some minutes and then occasionally until solution is complete. The solution may be warmed slightly but never above 50° C., and continuous mechanical stirring hastens the solution. When solution is complete, add a little ignited asbestos, wash down the sides of the beaker with a little acidulated $CuCl_2.2KCl$ solution and allow to settle. Filter on ignited asbestos in a Gooch crucible or, preferably, on a platinum boat.[1] Transfer the carbonaceous matter completely with dilute acidulated $CuCl_2.2KCl$ solution and scrub the sides of the beaker. Finally wash with distilled water until chlorides are absent and then dry at 100° C. When dry, burn in a combustion tube through which is passed a current of oxygen freed from all organic compounds. The post train should contain a tube containing pumice soaked in sulfuric acid saturated with chromic acid to oxidize and retain any sulfur dioxide and a tube containing $CuSO_4$

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[1] A. A. Blair, "The Chemical Analysis of Iron," 8th edition, Lippincott and Co., pp. 152-54.

dehydrated at 200° C. to catch any traces of HCl, in addition to the ordinary driers, carbon dioxide absorbers and protectors. The weight of carbon dioxide × 0.27273 represents the carbon in the sample.

ANALYSIS OF LIGHT ALUMINUM ALLOYS.

A. DETERMINATION OF SILICON (NON-GRAPHITIC, GRAPHITIC AND TOTAL), TITANIUM AND IRON.

DETERMINATION OF SILICON.

(NON-GRAPHITIC, GRAPHITIC AND TOTAL SILICON.)

Proceed as described under "Determination of Silicon" in Aluminum.

NOTE.

In case lead sulfate is present (as evidenced by a white crystallin precipitate quickly settling after stirring to the bottom of the casserole) the filtered precipitate must be washed free from the sulfate with an $HN_4C_2H_3O_2$ wash solution made up as follows: Take 20 cc. NH_4OH (sp. gr. 0.90) add 20 cc. of distilled water and make slightly acid with glacial acetic acid. The final washing must be made with hot water.

DETERMINATION OF TITANIUM.

(*a*) *In the absence of nickel.*

METHOD.

Proceed as described under "Determination of Titanium" in Aluminum.

NOTE.

Vanadium, which interferes in the test, should not be encountered in this class of material. Its presence would be betrayed by an "off" reddish-brown cast in the peroxidized solution.

(*b*) *In the presence of nickel.*

METHOD.

Dissolve 1 g. of the sample as described under "Determination of Tin and Antimony" below. If the nitric acid solution of the sodium hydroxide insoluble is not clear it must be filtered, the residue burned in platinum, fused with a little $K_2S_2O_7$, dissolved in a little 5-per-cent H_2SO_4 and added to the nitric acid filtrate. Dilute the nitric acid solution to 200 cc., treat with NH_4OH (sp. gr. 0.90) until ammoniacal, boil 3 minutes, filter and wash. Dissolve the precipitate in hot dilute

H_2SO_4 (25-per-cent) keeping the volume below 80 cc., cool and proceed with the colorimetric test as described under "Determination of Titanium" in Aluminum.

NOTES.

The above method provides for the color interference of copper and nickel when they are present in large amounts.

Vanadium (see Notes above) and other elements which would cause color interferences are not apt to occur in this class of material.

DETERMINATION OF IRON.

METHOD.

Proceed as described under "Determination of Iron" in Aluminum.

NOTES.

In case the alloy contains high percentages of copper, lead, tin or antimony it is preferable to treat the combined filtrate and washings from the silicon determination with H_2S and filter off and wash the sulfates. The solution should then be boiled free from hydrogen sulfide, treated with 10-per-cent $KMnO_4$ solution to a pink tint and then reduced as directed.

Reducible elements other than iron and titanium must be absent. Such elements are chromium, vanadium, molybdenum, tungsten and uranium, and they ordinarily will not be found in this class of material.

For the determination of iron in the presence of titanium see Notes under "Determination of Iron" in Aluminum.

DETERMINATION OF ANTIMONY, TIN, LEAD AND COPPER.

PRELIMINARY SEPARATION.

SOLUTIONS REQUIRED.

Sodium Hydroxide Solution (25-per-cent).—Dissolve 250 g. of NaOH in distilled water and dilute to 1000 cc. If a sediment forms on standing, decant the solution and filter through an asbestos pad. The NaOH must be entirely free from organic matter.

Nitric Acid (1 : 1).—Pour 500 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 1000 cc.

METHOD.

Dissolve 5 g. of the sample in a covered porcelain dish of suitable size in 125 cc. of (25-per-cent) NaOH solution. When solution is complete dilute with 100 cc. of distilled water, decant off the clear solution and wash the residue well with hot dilute NaOH solution

(2-per-cent). Treat the filtrate and washings with H_2S. If no precipitate appears, zinc is absent. In case a precipitate appears, zinc must be determined in a fresh sample as described further. Unfold the wet paper containing the NaOH insoluble and wash the residue back into the original vessel. Replace the paper in the funnel and pour 20 cc. of hot HNO_3 (1 : 1) over the paper and allow it to filter into the original vessel. Boil the residue until action ceases and oxides of nitrogen are expelled. Add 50 cc. of hot distilled water and allow to stand and settle for about one hour, keeping the temperature just below the boiling point. Filter on an ashless paper, being careful to keep the solution hot throughout the process of filtration, and receiving the filtrate in a 200-cc. beaker of the tall type used in electrolysis. Wash with boiling hot water. Retain the filtrate and washings for subsequent use in the copper and lead determinations and treat the residue as described under "Determination of Antimony."

NOTES.

Antimony will be quantitatively recovered with the tin provided it does not exceed one-fifth its amount. In the rare case of high antimony evaporate the nitric acid solution of the NaOH insoluble to dryness, bake at 105° C., take up in hot 10-per-cent by volume nitric acid, and proceed with the filtration and washing.

The metastannic acid precipitate will not contain enough copper to make a recovery worth while in ordinary work. As iron is determined in a separate portion and does not interfere in the determinations of antimony and tin, it may also be disregarded.

DETERMINATION OF ANTIMONY

SOLUTIONS REQUIRED.

Standard Permanganate Solution.—The solution prepared as under "Determination of Iron" may be employed. It must be standardized against weighed 0.05-g. portions of pure antimony or suitable material of known antimony content carried through the regular procedure after solution in acid and treatment in the Kjeldahl flask.

METHOD.

See "Preliminary Separation."

Transfer the filter containing metastannic acid and antimony oxide to a 500-cc. Kjeldahl flask, add 10 to 12 cc. H_2SO_4 (sp. gr. 1.84) and 3 to 5 g. Na_2SO_4. Heat until all organic matter is decomposed. Dilute, when cool, with 20 cc. of water. Add 0.5 g. Na_2SO_3 and boil until all SO_2 is expelled from the flask. Dilute to about 250 cc., add 20 cc. of HCl (sp. gr. 1.20) cool to 10° C. and titrate with the $KMnO_4$ solution to the first definite shade of pink. Reserve the solution for the "Determination of Tin."

DETERMINATION OF TIN.

SOLUTIONS REQUIRED.

Standard Iodine Solution.—Dissolve 10.7 g. of iodine in 50 cc. of water containing 20 g. of KI in solution, and dilute to 1000 cc. *when the iodine is completely in solution.* Standardize against pure tin by the method described below.

Starch Solution.—Prepare as described under "Determination of Copper, Iodide Method."

METHOD.

See "Determination of Antimony."

Transfer the solution used in "Determination of Antimony" to a 450-cc. Erlenmeyer flask, add an excess of powdered antimony and 50 cc. of HCl (sp. gr. 1.20). Attach a reflux condenser and boil for 15 minutes on a hot plate. Cool in a current of CO_2, add 5 cc. of starch solution, and without disconnecting the stream of CO_2, titrate with the iodine solution to the blue end point.

DETERMINATION OF COPPER AND LEAD SIMULTANEOUSLY. BY THE ELECTROLYTIC METHOD.

APPARATUS REQUIRED.

See "Determination of Copper" under "Analysis of Aluminum."

METHOD.

See "Preliminary Separation."

Dilute the filtrate and washings from the "Preliminary Separation" to about 150 cc. with distilled water and electrolyze, using weighed sand-blasted cathode and anode. Cover with a pair of split watch glasses and use a current of from 1.25 to 1.5 amperes, at approximately 10 volts for each solution. After about one hour the lead will have been entirely deposited on the anode as PbO_2; without interrupting the current add to the electrolyte 3 to 4 cc. of H_2SO_4 (sp. gr. 1.84), wash down the cover glasses, electrodes and sides of the beaker and continue the electrolysis for 15 minutes. If no darkening of the newly-exposed anode surface can be detected and if a few drops of H_2S water added to 1 cc. of the electrolyte on a porcelain plate gives no coloration the electrolysis is complete. In this case, remove the solution from the electrodes quickly without interrupting the current. Rinse the electrodes in quick succession with distilled water and then twice with alcohol. Reserve the electrolyte and water washings for the nickel and magnesium determinations. Dry the anode at 210° C. for thirty minutes. Weigh as PbO_2, using the factor for lead 0.8643 instead of the theoretical value. Shake off the excess alcohol from the cathode and ignite the remainder by bringing it to the flame of an alcohol lamp. Keep the cathode moving continually while the alcohol burns. Weigh as metallic copper.

NOTE.

The electrolyte and water washings may be diluted to 500 cc. and one 250-cc. portion taken for the "Determination of Nickel" and the other for the "Determination of Magnesium" as directed further. If the alloy contains copper and no tin, antimony or lead the electrolytic method given under "Determination of Copper" in Aluminum may be employed.

DETERMINATION OF LEAD AS SULFATE.

(OPTIONAL.)

SOLUTIONS REQUIRED.

"Lead Acid."—Mix 300 cc. of H_2SO_4 (sp. gr. 1.84) and 1800 cc. of distilled water. Dissolve 1 g. of lead acetate C.P. in 300 cc. of distilled water and add this to the hot solution, stirring meanwhile. Let stand at least 24 hours and siphon through a thick asbestos filter.

Dilute Alcohol for Washing.—Mix equal parts of denatured alcohol and distilled water.

METHOD.

See "Preliminary Separation."

To the combined filtrate and washings from the "Preliminary Separation" add 120 cc. of lead acid, and evaporate until copious fumes of H_2SO_4 are evolved. Cool, add 105 cc. of distilled water to dissolve the salts and to make the concentration the same as in the lead acid, heat to boiling, and allow to cool and settle for 5 hours, or over night if convenient. Filter on a weighed porcelain Gooch crucible and wash with lead acid. Set the filtrate and washings aside for the "Determination of Copper by the Iodide Method." Continue the washing and wash out the lead acid with dilute alcohol. Set the Gooch crucible inside a porcelain crucible, dry and ignite for 5 minutes at the full heat of a Tirrill burner. Cool and weigh as $PbSO_4$, which contains 68.32 per cent lead.

DETERMINATION OF COPPER
BY THE
IODIDE METHOD.
(OPTIONAL.)

METHOD.

See "Determination of Lead as Sulfate."

Dilute the reserved filtrate and washings from the "Determination of Lead as Sulfate" with an equal volume of water, treat with H_2S and proceed as directed in "Determination of Copper by the Iodide Method" under "Analysis of Aluminum."

DETERMINATION OF NICKEL
BY THE
DIMETHYLGLYOXIME METHOD.

SOLUTIONS REQUIRED.

Sulfuric Acid (1 : 1).—Pour 500 cc. of H_2SO_4 (sp. gr. 1.84) into distilled water, cool, and dilute to 1000 cc.

Hydrogen Sulfide Wash Water.—Add 10 cc. of H_2SO_4 (sp. gr. 1.84) to 1000 cc. of distilled water and saturate with H_2S.

Tartaric Acid Solution (20-per-cent).—Dissolve 20 g. of tartaric acid in distilled water, dilute to 100 cc. and filter if necessary.

Dimethylglyoxime Solution (1-per-cent).—Dissolve 10 g. of the reagent in 1000 cc. of 95-per-cent alcohol.

METHOD.

Dissolve 1 g. of the sample in 25 cc. of H_2SO_4 (1 : 1) as directed in "Determination of Manganese by the Persulfate Method." After oxides of nitrogen have been expelled add 14 cc. NH_4OH in order to bring down the acidity to approximately 5 cc. H_2SO_4 (sp. gr. 1.84) per 100 cc. of solution. Treat with hydrogen sulfide. Filter off the sulfides, wash with hydrogen sulfide wash water and boil the filtrate until H_2S is expelled. Add a few crystals of $(NH_4)_2S_2O_8$ and boil thoroughly to destroy sulfur and oxidize iron. Add 20 cc. of tartaric acid solution and make slightly ammoniacal. If no precipitate appears add HCl (sp. gr. 1.20) to slight acidity. If a precipitate appears, dissolve in HCl add 10 cc. of tartaric acid and again make ammoniacal, repeating the operation, if necessary, to get a clear solution. To the weakly acid solution add dimethylglyoxime in such an amount that the ratio of the reagent to nickel is at least 4 : 1. Heat the solution to boiling, and make slightly ammoniacal. Allow to digest while cooling for two hours. Collect on a weighed Gooch crucible and wash thoroughly with hot water. Dry for forty-five minutes at 110 to 120° C. and weigh. The nickel dimethylglyoxime contains 20.32 per cent of nickel.

NOTES.

In case copper and lead have been determined electrolytically, nickel may be determined in one 250-cc. portion of the electrolyte and washings (see Notes), starting with the $(NH_4)_2S_2O_8$ treatment to oxidize iron and then proceeding as directed in the method above.

Nickel may be precipitated by glyoxime, filtered, dissolved in nitric acid, made ammoniacal and titrated with cyanide solution according to Frevert's method.[1]

DETERMINATION OF MAGNESIUM.

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 1).—Pour 500 cc. of HCl (sp. gr. 1.20) into distilled water and dilute to 1000 cc.

Sulfuric Acid Wash Water.—Saturate 500 cc. of a 1-per-cent H_2SO_4 solution with H_2S.

Ammonium Sulfide Wash.—Take 10 cc. of NH_4OH, dilute to 500 cc., add 10 g. NH_4Cl and saturate with H_2S.

Microcosmic Salt Solution.—Prepare a clear saturated solution as required.

Ammoniacal Wash Solution.—Dissolve 50 g. of NH_4NO_3 in distilled water, add 50 cc. NH_4OH (sp. gr. 0.90) dilute to 1000 cc. and filter if necessary.

METHOD.

Dissolve 10 g. of the sample and wash the residue as directed under the "Preliminary Separation Determination of Antimony, Tin, Lead and Copper." Dissolve the residue in 10 cc. hot HCl (1 : 1) using a little HNO_3 if necessary. If the hydrogen sulfide group of metals are present, neutralize with NH_4OH, make weakly acid with HCl, dilute to 100 cc., heat and precipitate with hydrogen sulfide. Filter off the sulfides and wash with the H_2SO_4 wash water. To this filtrate or to the HCl solution if no H_2S treatment was required, add 5 cc. HCl (sp. gr. 1.20) make slightly ammoniacal and precipitate with H_2S. Filter and wash with the $(NH_4)_2S$ wash. Acidify the filtrate with HCl, boil off H_2S, add $(NH_4)_2S_2O_8$ and boil to destroy sulfur if necessary. Add 1 g. of tartaric acid and 30 cc. of microcosmic salt solution. Cool, and add NH_4OH (sp. gr. 0.90) drop by drop while stirring vigorously until a crystallin precipitate begins to form. Continue the very slow addition of NH_4OH with stirring until a precipitate no longer forms and then add one-tenth the volume of NH_4OH (sp. gr. 0.90) and let stand over night. Filter and wash with cold ammoniacal wash solution. Ignite slowly under oxidizing conditions in a tared porcelain or platinum crucible and finally heat over the blast lamp or its equivalent. Weigh as $Mg_2P_2O_7$. The weight multiplied by 0.2185 represents magnesium.

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[1] A. A. Blair, "The Chemical Analysis of Iron," 8th Edition, Lippincott and Co., pp. 182–3.

NOTE.

In case copper and lead were determined electrolytically one reserved portion of the electrolyte and washings (see Notes) may be used for the determination of magnesium, starting in with the addition of 5 cc. HCl (sp. gr. 1.20) and the precipitation of the $(NH_4)_2S$ group.

DETERMINATION OF MANGANESE.

(*a*) *Persulfate or Bismuthate Method.* (For samples containing under 1.50 per cent manganese.)

Proceed as directed in "Determination of Manganese" under "Analysis of Aluminum."

(*b*) *Nitric Acid and Potassium Chlorate Method.*[1] (For samples containing over 1.50 per cent manganese.)

SOLUTIONS REQUIRED.

Hydrochloric Acid (1 : 1).—Mix 500 cc. of HCl (sp. gr. 1.20) and 500 cc. of distilled water.

Sulfurous Acid.—Pass SO_2 from a cylinder into 500 cc. of cold distilled water until saturated.

Bromine Water.—Place 20 to 30 cc. of liquid bromine in a 500-cc. bottle, fill with cold distilled water, and shake thoroughly. ***Avoid any contact with the skin.***

Dilute Hydrochloric Acid (1 : 3.)—Pour 250 cc. of HCl (sp. gr. 1.20) into distilled water and dilute to 1000 cc.

Sodium-Ammonium Phosphate Solution.—Prepare this solution as needed by dissolving 1 part of the salt in 6 parts of cold water and filtering.

Ammonium Nitrate Solution.—Dissolve 100 g. of NH_4NO_3 in distilled water, make slightly ammoniacal, dilute to 1000 cc. and filter if necessary.

METHOD.

In a 250-cc. Erlenmeyer flask dissolve 1 g. of the sample in 30 cc. of HCl (1 : 1). When solution is complete add 25 cc. HNO_3 (sp. gr.

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[1] A. A. Blair, "The Chemical Analysis of Iron," 8th Edition, J. B. Lippincott and Co., pp. 108–115.

1.42) and evaporate until the solution is almost syrupy. Add 50 cc. of HNO_3 (sp. gr. 1.42) and 5 g. $KClO_3$. Heat the solution to boiling either on the hot plate or on a tripod with a thin piece of sheet asbestos, about 1 in. (25 mm.) in diameter, on the center of the wire gauze. Boil the solution 15 minutes, remove from the heat, add 50 cc. HNO_3 (sp. gr. 1.42) and 5 g. $KClO_3$ and boil 15 minutes longer or until yellowish fumes are no longer given off. Cool the solution rapidly in cold water and filter through asbestos. Wash two or three times with HNO_3 (sp. gr. 1.42) (free from oxides of nitrogen which dissolve the dioxide).

Transfer the dioxide with the asbestos filter to the beaker in which the precipitation was made. Pour from 10 to 40 cc. of strong sulfurous acid through the filtering apparatus into the beaker. As soon as the precipitate has dissolved, filter from the asbestos into a 150-cc. beaker, wash with hot water, and add 5 cc. HCl (sp. gr. 1.20). Heat to expulsion of SO_2, add bromine water until the solution is strongly colored with it, and boil off all excess bromine. Add NH_4OH in slight excess, boil for a few minutes, and filter into a 600-cc. beaker. Wash with hot water, remove and reserve the filtrate, and dissolve the precipitate in dilute HCl (1 : 3), allowing the solution to run back into the beaker in which the precipitation was made. Wash the filter with hot water. Boil the solution for 10 minutes to drive off any chlorine and reprecipitate by NH_4OH as before, filter into the reserved filtrate and repeat the solution, precipitation and filtration, allowing all the filtrates from the $Fe(OH)_3$ to run into the 600-cc. beaker. Acidulate this solution, which will be about 300 or 400 cc. in volume, with acetic acid, heat to boiling and treat with H_2S for 10 minutes. Filter, wash with a little dilute acetic acid saturated with hydrogen sulfide and boil off the hydrogen sulfide after adding 5 cc. of HCl (sp. gr. 1.20). Add from 5 to 20 cc. of a clear filtered solution of microcosmic salt, heat to boiling, and add NH_4OH drop by drop with constant stirring. When the precipitate begins to form, stop the addition of NH_4OH and stir until the precipitate becomes crystallin. When this change occurs add one more drop of ammonia; the additional precipitate formed will be curdy, but a few seconds stirring will change it to the silky crystallin condition. Continue the addition of NH_4OH in exactly the same manner until the precipitate is all down and further additions of NH_4OH fail to change the silky appearance. Add a dozen drops of NH_4OH in excess and cool the beaker in ice water. Filter the precipitate on an asbestos filter, wash with the cold NH_4NO_3 solution until the filtrate gives no reaction for HCl.

Dry, ignite and weigh as $Mn_2P_2O_7$ which contains 38.69 per cent manganese.

NOTES.

The Ford method is recommended only where extreme accuracy is desired; otherwise use the persulfate or bismuthate methods.

If a cylinder of SO_2 is not available, hydrogen peroxide will serve equally well for the solution of the hydrated manganese dioxide.

DETERMINATION OF ZINC.

(*a*) *Samples containing up to 3 per cent of zinc.*

SOLUTIONS REQUIRED.

Dilute Hydrochloric Acid (1 : 1).—Pour 500 cc. of HCl (sp. gr. 1.20) into distilled water and dilute to 1000 cc.

Acid Wash Water.—Pour 10 cc. of H_2SO_4 (sp. gr. 1.84) into 1000 cc. of distilled water and saturate with H_2S.

Formic Acid Mixture.—Treat 400 cc. of formic acid with 60 cc. of NH_4OH (sp. gr. 0.90) and dilute to 2000 cc.

Formic Acid Wash Water.—Pour 25 cc. of formic acid mixture into 1000 cc. of distilled water and saturate with H_2S.

Dilute Hydrochloric Acid (1 : 10).—Pour 100 cc. of HCl (sp. gr. 1.20) into distilled water and dilute to 1000 cc.

Bromine Water.—See "Determination of Manganese, Nitric Acid and Potassium Chlorate Method."

METHOD.

Dissolve 1 g. of the sample in a covered 400-cc. beaker in 25 cc. of dilute HCl (1 : 1), with the addition of 1 cc. of HNO_3 (sp. gr. 1.42) toward the end of the reaction. Boil to expel oxides of nitrogen and dilute to 200 cc. Precipitate the H_2S group, filter and wash with acid wash water. Boil thoroughly to expel H_2S, cool, and add 5 g. of citric acid crystals. Neutralize with NH_4OH, using methyl orange as an indicator and then add 25 cc. of the formic acid mixture. Dilute to 300 cc., heat nearly to boiling and pass in H_2S until the solution is cold. Filter and wash with the formic acid wash water. Dissolve the zinc sulfide off the filter with warm dilute HCl (1 : 10) and wash the filter with hot water. Boil the solution to expel H_2S. Cool, add 1 g. of citric acid crystals, neutralize with NH_4OH, using methyl orange as an indicator and then add 20 cc. of the formic acid mixture. Dilute to 200 cc. and proceed as before through the filtration on an ashless paper and washing of the sulfide. Dissolve the precipitate with hot dilute HCl, and transfer the solution to a weighed platinum or porcelain dish or crucible. Add a few drops of H_2SO_4 (sp. gr. 1.84) and evaporate the solution until copious fumes escape. If the solution is not clear and colorless, cool, add a few cubic centimeters of HNO_3 (sp. gr. 1.42) and again evaporate the solution until fumes of H_2SO_4 come off freely. Repeat the treatment with HNO_3 if necessary, until the organic matter is destroyed, and the solution is colorless. Remove the excess of H_2SO_4 by heating the dish cautiously, and finally heat at a temperature just below dull redness. Weigh as $ZnSO_4$, which contains 40.49 per cent of zinc.

NOTE.

The use of a sodium hydroxide solution of the turnings is not recommended for the determination of zinc on account of uncertainty as to the completeness of the solution of the zinc in all cases.

(*b*) *Samples containing over 3 per cent of zinc.*[1]

SOLUTIONS REQUIRED.

Ferrous Sulfate Solution.—Dissolve 3 g. of $FeSO_4 . 7H_2O$ in distilled water, add 10 cc. of HCl (sp. gr. 1.20) and dilute to 1000 cc.

Ferrocyanide Solution.—Dissolve 44 g. of K_4FeCN_6 and 0.3 g. of K_3FeCN_6 in distilled water, dilute to 1000 cc. and age six weeks before standardization as follows: Dissolve 6 g. of zinc of known content in 40 cc. of HCl (sp. gr. 1.20) in a 2-liter flask. Cool and make up to the mark. Take 100-cc. portions, add 20 cc. of HCl (1 : 1) and add 13 cc. of NH_4OH (sp. gr. 0.90) and proceed with the titration as directed below.

METHOD.

Proceed as in the previous method until the first zinc sulfide precipitate has been obtained. Return the paper and precipitate to the original beaker and add 20 cc. of HCl (1 : 1). When the sulfide has dissolved, filter off the paper together with some sulfur and possibly a little nickel sulfide. Boil the solution containing the zinc to expel H_2S, cool, and wash down. Add 13 cc. of NH_4OH (sp. gr. 0.90) and if the solution is not alkaline, add NH_4OH carefully until it is. Make the solution barely acid again with HCl (1 : 1) and add 3 cc. of HCl (sp. gr. 1.20) in excess. Add 1 cc. of $FeSO_4$ solution, dilute nearly to 200 cc., heat almost to boiling and titrate with the K_4FeCN_6 solution. The end point is a sharp change in the color of the solution from a turquoise blue to a "pea green" and with several more drops to a "creamy yellow."

NOTE.

The end point occurs a little sooner than the one with uranium nitrate, and is easier to use, as the change is seen directly in the solution.

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[1] Method of F. G. Breyer, 8th International Congress of Applied Chemistry 1, 162; see also, "Analysis of Copper," G. L. Heath, McGraw-Hill Book Co., pp. 250, 251.

DETERMINATION OF CARBON.

Determine carbon as described under "Analysis of Aluminum."

DETERMINATION OF SODIUM.

SOLUTIONS REQUIRED.

Dilute Nitric Acid (1 : 2).—Pour 250 cc. of HNO_3 (sp. gr. 1.42) into distilled water and dilute to 750 cc.

Saturated Ammonium Carbonate Solution.—Small quantities made up as required.

METHOD.

Dissolve 5 g. of the sample in a porcelain dish in 100 cc. of dilute HNO_3 (1 : 2) by continued digestion at 50 to 60° C. When solution is complete, evaporate the solution to dryness and heat on a sand bath for several hours to complete decomposition of aluminum nitrate, but without melting any sodium nitrate formed. Cool the residue, take it up in boiling distilled water, filter and wash thoroughly. Treat the water extract with saturated $(NH_4)_2CO_3$ solution, heat to boiling and filter if a precipitate forms. Evaporate the clear filtrate in a weighed platinum dish, treat the residue with sufficient H_2SO_4 to convert the nitrate to sulfate, continue the evaporation and finally heat at 300 to 400° C. to complete expulsion of H_2SO_4. Weigh as Na_2SO_4. A blank should be carried through all operations and the proper correction applied.

DETERMINATION OF NITROGEN.

SOLUTIONS REQUIRED.

Sodium Hydroxide Solution (10-per-cent).—Dissolve 100 g. of NaOH in distilled water, dilute to 1000 cc. and filter through asbestos if the solution develops a sediment upon standing.

Approximate N/10 Sulfuric Acid Solution.—Pour 2.8 cc. of H_2SO_4 (sp. gr. 1.84) into 1000 cc. of distilled water and standardize by any standard method.

Approximate N/10 Sodium Hydroxide Solution.—Dissolve 4.5 g. of NaOH in distilled water and dilute to 1000 cc. This solution should be standardized against the standard acid solution.

METHOD.

Place 3 to 4 g. of the sample in a Kjeldahl flask fitted with a two-hole stopper carrying a separatory funnel and a trap connected with a condenser as in a Kjeldahl determination of nitrogen. Add 400 cc.

of the NaOH solution through the separatory funnel, and allow the generated gas to bubble through 50 cc. of N/10 sulfuric acid solution. When the reaction has ceased, boil the alkaline solution to expel all ammonia. Finally titrate the acid with N/10 sodium hydroxide in the usual manner and calculate nitrogen.

DETERMINATION OF ALUMINUM AND ALUMINUM OXIDE.

SOLUTIONS REQUIRED.

Sodium Hydroxide Solution (10-per-cent).—Dissolve 100 g. of NaOH in distilled water and dilute to 1000 cc. If a sediment forms on standing, decant the solution and filter through an asbestos pad.

Sodium Carbonate Solution.—Dissolve 36 g. of Na_2CO_3 in distilled water, dilute to 1000 cc., and filter if necessary.

Barium Chloride Solution.—Dissolve 90 g. of $BaCl_2.2H_2O$ in distilled water, dilute to 1000 cc., and filter if necessary.

Dilute Hydrochloric Acid.—Dilute 500 cc. of HCl (sp. gr. 1.20) with 500 cc. of water.

Methyl Red Indicator.—Dissolve 0.02 g. of the acid in 100 cc. of distilled water.

Ammonium Chloride Wash Solution.—Dissolve 50 g. of NH_4Cl in distilled water, make sure the solution is just alkaline to methyl red, dilute to 1000 cc. and filter if necessary.

Dilute Nitric Acid (1 : 1).—Dilute 500 cc. of HNO_3 (sp. gr. 1.42) with 500 cc. of distilled water.

Acid Wash Water.—Add 5 cc. of H_2SO_4 (sp. gr. 1.84) to 500 cc. of water and saturate with H_2S.

PRELIMINARY TREATMENT.

Place 2 g. of the sample in a suitable porcelain dish, add 60 cc. of the NaOH solution (10-per-cent), cover with a glass, and cool in water if the reaction proceeds too violently. When violent action ceases, wash the cover-glass and sides of the vessel, replace the glass and warm on a sand bath or steam-box until reaction ceases. These operations should be carried on expeditiously. Filter and wash the residue with hot NaOH solution (10-per-cent). Reserve the residue and treat the filtrate and washings as below.

(*a*) *Determination of Aluminum.*

Cool the filtrate and washings to room temperature, dilute to exactly 500 cc. and mix thoroughly. Transfer pipetted 50-cc. portions to 600-cc. beakers, add 10 cc. of HCl (sp.gr. 1.20), place on water bath and evaporate to dryness. When dry, continue the heating for one hour more. Take up the residue in cold distilled water, transfer to a flask and add a mixture of 50 cc. of the Na_2CO_3 solution and 50 cc. of the $BaCl_2$ solution. Shake thoroughly and allow to settle. Filter, wash with cold water, and then transfer the precipitate to the original flask by piercing the paper and washing down with boiling water, finally with dilute HCl, adding enough to dissolve the precipitate and avoiding mechanical loss. Evaporate the solution to one-third volume, add a few drops of methyl red and then NH_4OH (sp. gr. 0.90) until the indicator just turns yellow. Boil for three minutes, filter and wash with warm 5-per-cent NH_4Cl solution. Bring the precipitate back into the beaker as before, dissolving all $Al(OH)_3$ on the paper and evaporate the solution to dryness. Drench with a little HCl (sp. gr. 1.20) add hot water and warm until salts are in solution. Filter in case a residue is present, reprecipitate $Al(OH)_3$ and wash as above. Place the wet paper and contents in a tared crucible (with cover and preferably of platinum), dry, ignite carefully in an oxidizing atmosphere and finally cover and blast strongly. Weigh as Al_2O_3 and calculate aluminum.

NOTES.

This method is a modification of the method proposed by J. G. Rhodin, Faraday Society Trans., *14*, (1918–19) pp. 135–7 and presupposes complete solubility of aluminum and insolubility of aluminum oxide in a 10-per-cent solution of NaOH.

It is important that the "50-cc." pipette deliver exactly one-tenth of the "500-cc." volume.

Two precipitations with NH_4OH are necessary to eliminate barium and the intervening evaporation to dryness is desirable in case silica is present.

(*b*) *Determination of Aluminum Oxide.*

See "Preliminary Separation."

Transfer the residue insoluble in NaOH solution (10-per-cent) to a small flask and treat the paper with hot dilute HNO_3 (1 : 1). When solution of the residue is complete, dilute to 100 cc., neutralize with NaOH solution (10-per-cent), add 3 cc. HCl (sp. gr. 1.20) and treat with hydrogen sulfide. Filter, wash the sulfides with acid wash water and boil the filtrate and washings until H_2S is expelled, using a few crystals of $K_2S_2O_8$ if sulfur separates. Pour the hot solution slowly and with stirring into 50 cc. of boiling hot NaOH solution (10-per-cent). Filter and wash with a little hot NaOH solution (10-per-cent).

In case the precipitate is large, dissolve it and reprecipitate. Acidify the NaOH filtrate or filtrates with HCl (sp. gr. 1.20) and precipitate $Al(OH)_3$ as described in (*a*) above. A second precipitation should be carried out in case the precipitate is large, and always in accurate work. Ignite, weigh as Al_2O_3 and report as such.

TENTATIVE METHODS OF CHEMICAL ANALYSIS OF NICKEL.[1]

Serial Designation: B 41 – 21 T.

These methods are issued under the fixed designation B 41 ; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

DETERMINATION OF IRON.

(*a*) *By the Cuprous Chloride Method.*

SOLUTIONS REQUIRED.

Cuprous Chloride Solution.—Place into a 2-liter heavy glass bottle, 400 g. NaCl, 100 cc. HCl and 20 g. Cu_2Cl_2. Add 2 liters of warm water; shake well; place into the solution a few copper rods and let stand over night in a cool place. After shaking, the solution is ready for use.

1 cc. Cu_2Cl_2 should reduce 0.003 g. to 0.005 g. of iron.

METHOD.

Dissolve 10 g. of nickel drillings in 100 cc. dilute HNO_3 (1 : 2) in a 600-cc. covered beaker, add 1 or 2 g. $KClO_3$, boil for 30 minutes, add about 100 cc. cold water, make alkaline with NH_4OH and add about 50 cc. in excess. Boil a few minutes, filter, wash the precipitate with hot water two or three times.

Re-dissolve the precipitate in hot HCl (1 : 3). After the precipitate is dissolved make the solution alkaline with NH_4OH, boil a few minutes, filter and wash with hot water. Dissolve the $Fe(OH)_3$ in 30 cc. hot HCl (1 : 3) in a 24-oz. flask, cool, add about 300 cc. cold water and titrate with a standard Cu_2Cl_2 solution using two drops of a saturated solution of KCNS as an inside indicator. Titrate to faint opalescence.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably befo, January 1, 1922, to Mr. P. D. Merica, Secretary of Committee B-2 on Non-Ferrous Metals and Alloy International Nickel Co., Bayonne, N. J.

NOTES.

The Cu_2Cl_2 solution should be standardized each time before using, with 10 cc. of standard ferric chloride, to which 5 cc. of HCl is added, diluted to 300 cc. with cold water and titrated to faint opalescence. The ferric chloride is made by dissolving 5 g. of standard iron wire in 150 cc. of HCl (1 : 1); then 5 g. $KClO_3$ is added to oxidize the iron. Add 1 liter of water and boil until all the free chlorine is driven off. Boil about eight hours, keeping the volume of the solution about one liter, then cool and make the solution up to two liters.

The above method is used for determining iron in material with less than 5 per cent iron, using a 1-g. sample, and when less than 0.5 per cent using a 10-g. sample.

The solution gains in Cu_2Cl_2, and should now and then be diluted with a solution containing 20 per cent of NaCl and 5 per cent of HCl. If the solution should fall off in Cu_2Cl_2, add about 5 g. Cu_2Cl_2.

(*b*) *By Potassium Permanganate Method.*

SOLUTIONS REQUIRED.

Standard Potassium Permanganate Solution.—Standardized by means of sodium oxalate (as furnished by the Bureau of Standards).

METHOD.

Dissolve the $Fe(OH)_3$ in dilute H_2SO_4 and reduce the iron with Zn, and then titrate with $KMnO_4$.

NOTE.

This method is just as accurate as the Cuprous Chloride Method providing 5 g. of the drillings are taken.

DETERMINATION OF CARBON.

BY THE DIRECT COMBUSTION METHOD.

APPARATUS.

Purifying Train.—The purifying train should consist of a 5-in. "U" tube filled with glass beads and moistened with H_2CrO_4 solution, with a loose plug of glass wool in the forward end. This serves to oxidize any SO_2 and to absorb the SO_3 formed from the sulfur in the nickel drillings during combustion. This tube should be washed out daily and fresh glass wool inserted.

Material for Lining Boats.—The boat may be filled with ignited alumina. Alundum, "RR Alundum, alkali-free, specially prepared for carbon determination" is also recommended.

Catalyzers.—The forward end of the platinum combustion tube should contain a plug of loosely wound platinum gauze, 5½ in. long, completely filling the bore of the tube and a similar roll 2 in. long, fitted with a loop, pushed in after the boat.

Combustion Apparatus.—The apparatus may be heated by gas or electricity and combustion tubes may be of platinum, quartz, or porcelain glazed on one or both sides.

Boats or Other Containers of Samples being Burned.—These may be of alundum, but porcelain, quartz, clay and platinum are also recommended.

Absorption Train.—It is recommended that the absorption train consist of a Geissler potash bulb with a calcium chloride tube attached.

REAGENTS.

Oxygen.—Oxygen of not less than 97-per-cent purity is recommended. Endeavor should be made to obtain oxygen which gives no blank since the correction for or elimination of this is troublesome and uncertain. For the most accurate work the blank should be completely eliminated by the use of a catalyzer before the furnace with a CO_2 absorbent interposed between the furnace and the catalyzer.

Potassium Hydroxide Solution.—A KOH solution (sp. gr. 1.27) should be used as the absorbent for CO_2 but the use of "Ascarite" is also recommended.

FACTORS INFLUENCING RAPID COMBUSTION.

Size of Particles of Sample.—The finer the chips the better, except with samples which burn too vigorously. Particles too coarse to pass a 20-mesh sieve are not recommended, nor long, curly drillings which will not pack closely. Oil, dust and other foreign matter should be carefully excluded.

Manner of Distributing Sample in Boat.—This is of considerable importance. With all samples, close packing in a small space is conducive to rapid combustion. In the case of samples which burn too vigorously, a satisfactory regulation may sometimes be attained by spreading the sample loosely over the lining in the boat.

Rate of Admitting Oxygen.—The valve controlling the supply of oxygen must be regulated so as to keep a slow current of gas passing through the absorption apparatus at all times and not to exceed three bubbles in a second.

METHOD.

After having properly set up and tested the apparatus, fill the alundum boat with ignited alumina and make a "V"-shaped depression in the middle with a spatula, pressing the material against the sides of the boat. Ignite the boat and its contents strongly to expel any CO_2 present and burn off any carbonaceous matter that the alumina may contain. Weigh out 3 g. of nickel drillings which have been broken down so as to pass through a 20-mesh sieve and transfer it to the boat. Introduce the boat into the combustion apparatus. Burn the carbon by starting a slow current of oxygen and lighting one of the burners at the forward end of the tube, and as soon as the tube is red hot increase the heat slowly by lighting the other burners. Nickel is burned at a temperature of 1200° C. for 20 minutes.

DETERMINATION OF SULFUR.

SOLUTIONS REQUIRED.

Barium Chloride.—A 20-per-cent solution should be used.

METHOD.

Weigh duplicate 10-g. samples of drillings, place each into an 800-cc. casserole and treat as follows:

Add 3 g. of $KClO_3$, cover and then add 200 cc. strong HNO_3. Place on steam bath until action has ceased and then evaporate to dryness on the hot plate. Cool and then add 50 cc. HCl and again evaporate to dryness. Repeat this operation. Take up with 150 cc. water, add 8 cc. HCl, heat to boiling, filter and wash, taking care that the filtrate and washings do not exceed 300 cc. in volume. Heat the filtrate to boiling, add 25 cc. of 20-per-cent $BaCl_2$ solution and allow it to stand in a warm place over night. Filter through a small double ashless filter paper and wash with very dilute HCl, and finally with hot water. Ignite in a small platinum crucible and then heat to bright redness for twenty minutes. Cool and weigh the $BaSO_4$.

NOTES.

$BaSO_4 \times 0.1373 =$ sulfur.

Run a blank analysis, that is, take an 800-cc. casserole, add to it all the reagents and subject the contents to the same operations as the samples of drillings at the same time. Deduct any $BaSO_4$ obtained from the result of the actual assay. If this blank amounts to 0.0040 g., the reagents are unfit for the above analysis and the determinations should be repeated with other reagents.

DETERMINATION OF NICKEL AND COBALT.

(*a*) *By Electrolysis.*

APPARATUS.

Electrodes.—It is recommended that the cathode consist of a platinum cylinder 50 mm. by 38 mm. in diameter; with stem diameter $1\frac{1}{2}$ mm. and height 127 mm.

The anode should consist of a spiral of iron wire $1\frac{1}{2}$ mm. in diameter.

METHOD.

Dissolve 2 g. of nickel drillings in 30 cc. of HNO_3 (1 : 1) in a 400-cc. covered beaker, add 30 cc. HS_2O_4 (1 : 1) and evaporate until fumes of H_2SO_4 are given off copiously. Dilute with 250 cc. of water. Boil, cool and precipitate the copper with H_2S. Filter into a 600-cc. plain beaker, wash the precipitate with hot water, boil the filtrate gently until about one-third of the volume is evaporated, to remove the H_2S. Add 10 cc. H_2O_2 to oxidize the iron, cool, add 100 cc. NH_4OH water, then plate out the nickel and cobalt on a weighed platinum cylinder using a current of 0.6 ampere. It takes about 14 hours to plate out the nickel.

Make a replate on solution to recover the small amount of nickel which is left.

To make the replate, remove the beaker, add H_2SO_4 to the solution until acid, then add about 5 cc. in excess, cool, add 60 cc. NH_4OH water, then plate out nickel with a current of 1 ampere for two hours. Wash the cathode with water and alcohol, heat over an alcohol lamp and when cool weigh. Increased weight equals nickel and cobalt.

The cathode on which the nickel and cobalt have been plated is placed in a 125 cc. plain beaker. Dissolve the nickel and cobalt in dilute HNO_3 and remove the cathode. Evaporate the solution to a syrupy consistency, cool, add 25 cc. water, boil, neutralize with K_2CO_3 solution, make slightly acid with 50-per-cent acetic acid, then add 10 cc. of 50-per-cent acetic acid and make the volume up to 50 cc. In another beaker, dissolve 25 g. KNO_2 in 50 cc. water, and make acid with acetic acid. Add the nitrite solution to the solution containing the nickel and cobalt, while boiling. Let stand in a warm place over night. Filter and wash the precipitate with a 5-per-cent KNO_2 solution made acid with acetic acid. The precipitate is transferred to a 300-cc. beaker by washing with hot water and dilute H_2SO_4, add 20 cc. H_2SO_4 (1 : 1) and evaporate until fumes of sulfuric acid are given off copiously. Dilute with 150 cc. water. Boil, cool and add 100 cc. NH_4OH water. Plate over night using a current of 0.5 ampere. Weigh as cobalt.

Subtract the percentage of cobalt found from the percentage of cobalt and nickel. The difference is nickel.

NOTE.

When manganese is present, a solution containing 30 cc. of water and 2 g. of Na_2O_2 is added to the alkaline solution just before plating out the nickel and cobalt and also just before making the replate on the solution.

TENTATIVE SPECIFICATIONS

FOR

CLAY SEWER BRICK.[1]

Serial Designation: C 32 – 21 T.

These specifications are issued under the fixed designation C 32; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover four classes of clay bricks intended to be used in drainage structures for the conveyance of sewage, industrial waste and storm water, as follows, the purposes for which they are intended to be especially suitable being indicated:

Class A Vitrified Brick, for the interior of structures where resistance to the abrasive action of velocities up to 18 ft. per sec. is required.

Class B Vitrified Brick, for the interior of structures where resistance to the abrasive action of velocities up to 12 ft. per sec. is required.

Hard Brick, for structures requiring imperviousness to internal and external pressures and resistance to the abrasive action of velocities up to 8 ft. per sec.

Medium Brick, for storm water conduits, where a high degree of imperviousness is not required and where abrasive action is due to low velocities only.

For definitions of the above classes, see Table I.

Basis of Purchase. 2. The consumer or purchaser shall specify the class or classes of brick to be supplied.

Acceptance. 3. (*a*) The acceptability of brick shall be determined (*1*) by the results of the chemical and physical tests hereinafter specified, and (*2*) by visual inspection, to determine whether the bricks comply with the specifications as to dimensions, shape and freedom from visible defects.

(*b*) The acceptance of brick as satisfactorily meeting one of these two general requirements shall not be construed as in any way waiving the other.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. W. E. Emley, Secretary of Committee C-3 on Brick, Bureau of Standards, Washington, D. C.

I. MATERIALS.

Materials.

4. (*a*) Clay bricks shall be manufactured from surface clay, fire clay or shale or a combination of these materials.

(*b*) By *surface clay*[1] is meant an unstratified, unconsolidated, plastic glacial or alluvial clay, laid down by the glacial ice sheet, or on the flood plains of rivers, during the present geological epoch.

(*c*) By *fire clay*[1] is meant a stratified clay, usually buff-burning, usually less indurated than shales, with poorly marked cleavage, laid down prior to the present geological epoch.

(*d*) By *shale*[1] is meant a stratified clay, usually red-burning, more or less indurated by heat or pressure, with well-marked cleavage, laid down prior to the present geological epoch.

(*e*) The material shall possess such physical and chemical properties that when molded into bricks and subjected to a suitable temperature the product will be strong, durable and serviceable, free from objectionable defects and in compliance with these specifications and tests.

II. SIZE.

Standard Sizes.

5. Sewer brick shall be not less than $2\frac{1}{4}$ by $3\frac{3}{4}$ by 8 in. nor more than $2\frac{1}{2}$ by 4 by $8\frac{1}{2}$ in., except that No. 1 vitrified brick may be 3 by 4 by $8\frac{1}{2}$ in. but not more than $3\frac{1}{2}$ by 4 by $8\frac{1}{2}$ in.

III. SAMPLING.

Sampling.

6. For the purpose of tests, bricks shall be selected by a competent person appointed by the purchaser, the point or points of selection to be designated when the order is placed. The manufacturer or seller shall furnish specimens for tests without separate charge. All bricks shall be carefully examined and their condition noted before being subjected to any test. No sample which fails to meet the requirements of the visual inspection as given below shall be subjected to test. For the purpose of the tests not less than 15 bricks shall be required for each delivery; they shall be dried to constant weight in a suitable oven at a temperature of from 225 to 250° F. (107 to 121° C.).

IV. CHEMICAL TESTS AND REQUIREMENTS.

Chemical Tests.

7. The consumer or purchaser may prescribe in advance special chemical requirements in cases where sewage, industrial wastes or ground waters have a marked acid or alkaline character or are of

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[1] Definitions of the terms shale, fire clay and surface clay and of clays in general as applied to refractories, are now under consideration by Committee E-8 on Nomenclature and Definitions, in cooperation with the several standing committees interested.—ED.

abnormally high temperatures. He may make use of chemical analyses of the brick or brick materials to detect deleterious materials such as caustic lime, iron pyrites or any other materials which are known to cause slaking or disintegration. Such deleterious matter contained in the brick material shall be cause for rejection.

V. PHYSICAL TESTS.

Physical Tests.

8. (*a*) The brick shall be subjected to absorption, compression and transverse tests and shall meet the requirements specified in Table I for such tests.

(*b*) The standing of any set of bricks shall be determined by that one of the three requirements in which it is the lowest.

Absorption.

9. (*a*) At least five bricks after being dried to constant weight shall be completely submerged in water at a temperature of between 60 and 80° F. (15 and 27° C.). The water shall be heated to boiling within one hour, boiled continuously for five hours and then allowed to cool to a temperature between 60 and 80° F. (15 and 27° C.). The brick shall then be removed, the surface water wiped off with a damp cloth and the bricks quickly weighed.

(*b*) The percentage of absorption shall be calculated on the dry weight from the formula:

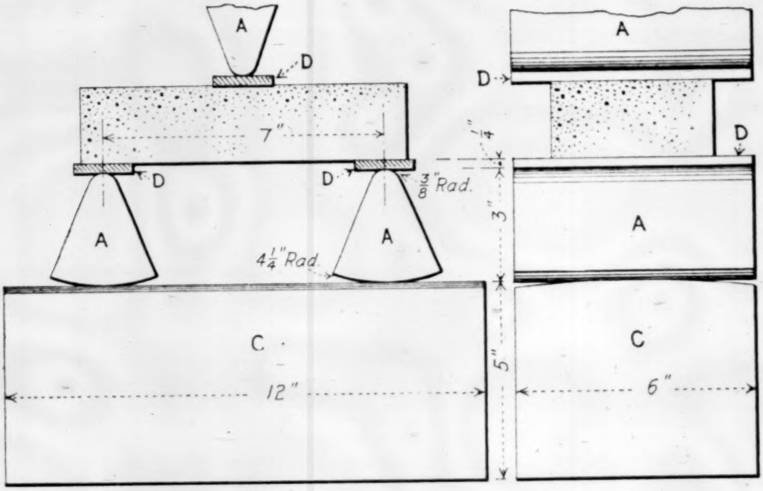
$$\text{Percentage of Absorption} = \frac{100\ (b-a)}{a}$$

where a = weight of dry brick and b = weight of saturated brick.

Compression Test.

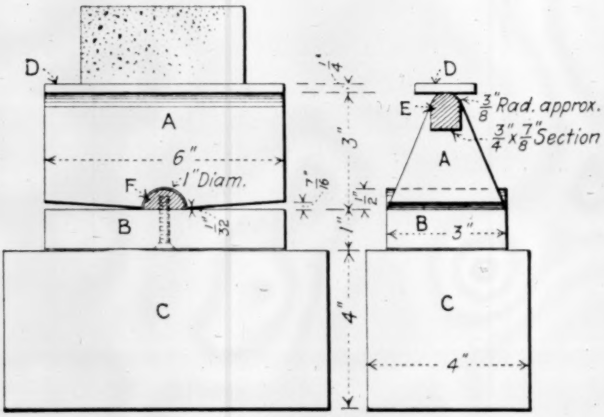
10. (*a*) Compression tests shall be made on at least five half bricks, previously dried, each taken from a different brick. The half brick shall be prepared either by sawing or cutting upon a yielding bed with a sharp mason's chisel, which shall be the full width of the brick. The specimens shall be tested on edge. To secure a uniform bearing in the testing machine the edge surface shall be bedded in a thin coat of calcined gypsum (plaster of Paris) spread upon plate glass previously coated with a film of oil. Before applying the calcined gypsum (plaster of Paris), the bearing surface of the brick shall receive a coating of shellac. The brick shall be pressed firmly upon the surface, making the layer as thin as possible and be permitted to remain undisturbed until set.

(*b*) The machine used for the compression tests shall be equipped with a spherical bearing block kept thoroughly lubricated to insure accurate adjustment, which should be made by hand under a small initial load. The radius of the spherical bearing surface should be such that the center of the sphere falls in the adjacent end surface of


A
D
7"
D
D
$\frac{3}{8}$" Rad.
A
A
$4\frac{1}{4}$" Rad.
C
12"
$\frac{1}{4}$"
3"
5"
A
D
D
A
C
6"

A = Cast-Iron Wedges; *C* = Soft Wood Block; *D* = Cold-Rolled Steel Plates.

FIG. 1.


D
A
6"
1" Diam.
F
B
C
$\frac{1}{4}$"
3"
$\frac{7}{16}$"
$\frac{1}{2}$"
1"
$\frac{1}{32}$"
4"
D
E
$\frac{3}{8}$" Rad. approx.
$\frac{3}{4}$" x $\frac{7}{8}$" Section
A
B
3"
C
4"

A, *B* = Cast-Iron Wedges; *C* = Soft Wood Block;
D, *E*, *F* = Cold-Rolled Steel.

FIG. 2.

the specimen. During the test the beam of the testing machine shall be kept constantly in a floating position.

(*c*) The breaking load shall be divided by the area in compression and the results reported in pounds per square inch.

Transverse Test.

11. (*a*) At least five bricks, previously dried, shall be tested, laid flat-wise on knife edges with a span of 7 in. and with the load applied at midspan. Steel bearing plates, about $\frac{1}{4}$ in. thick by $1\frac{1}{2}$ in. wide, may be placed between the knife edges and the brick. The use of a wooden base block, slightly rounded transversely across the top, upon which to rest the lower knife edges (see Fig. 1), or the form of lower knife edge shown in Fig. 2, is recommended. If the knife edges shown in Fig. 2 are used, they should rest upon smooth plane blocks of wood at least 2 in. thick.

(*b*) The modulus of rupture shall be calculated in pounds per square inch by the following formula:

$$R = \frac{3\,Wl}{2\,bd^2}$$

in which l equals the distance between supports in inches, b equals the breadth and d equals depth of the brick in inches, and W equals the load in pounds at which the brick failed. The measurement d is taken at the fractured surface after the specimen is broken.

TABLE I.—PHYSICAL TEST REQUIREMENTS FOR DIFFERENT CLASSES OF BRICK.

Class.	Absorption Limits, per cent.		Compressive Strength (on edge), lb. per sq. in.		Modules of Rupture, lb. per sq. in.	
	Mean of 5 Tests.	Individual Maximum.	Mean of 5 Tests.	Individual Minimum.	Mean of 5 Tests.	Individual Minimum.
Class A Vitrified.	3 or less	....	5000 or over	....	1200 or over	...
Class B Vitrified.	5 or less	6.0	5000 "	4000	1200 "	800
Hard...........	5 to 10	12.0	3500 "	2500	600 "	400
Medium.........	10 to 15	17.0	2000 "	1500	450 "	300

VI. VISUAL INSPECTION.

Visual Inspection.

12. (*a*) All brick shall be given a thorough visual inspection at the sewer trench by a competent inspector employed by the purchaser to determine whether the brick, independently of the chemical and physical requirements, comply with the specifications of general properties as follows:

(*b*) Bricks shall be of rectangular cross-section, full size and of uniform dimensions throughout. Recessed bricks shall not be accepted.

(*c*) Bricks shall have straight, parallel edges and square corners. The ends and at least one edge shall have a smooth plane surface; kiln marks not exceeding $\frac{1}{16}$ in. in depth shall be permitted on the opposite edge.

(*d*) Bricks shall be thoroughly and uniformly burned and when broken shall show a fracture of uniform and compact texture.

(*e*) The color of the bricks shall be considered to indicate their burning, providing the meaning of the variation in color be first determined from an investigation of the materials and the process of manufacture.

(*f*) Bricks shall be free from checks or cracks extending into the body of the brick in a manner that would affect their serviceability or strength. Bricks shall be free from stones, pebbles, and visible grains or masses of lime.

(*g*) Bricks when struck together or when struck with a trowel shall give a clear ringing sound.

TENTATIVE SPECIFICATIONS
FOR
QUICKLIME FOR STRUCTURAL PURPOSES.[1]

Serial Designation: C 5-21 T.

These specifications are issued under the fixed designation C 5; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Definition. 1. Quicklime is a calcined material, the major part of which is calcium oxide or calcium and magnesium oxides, which will slake on the addition of water.

General Quality. 2. Quicklime for structural purposes shall be properly burned and picked practically free from ashes, core, clinker, or other foreign material. It is sold either:

(*a*) *Screened.*—That from which the fine material has been removed, or

(*b*) *Unscreened.*—That from which the fine material has not been removed.

I. CLASSES AND SIZES.

Sizes. 3. Quicklime is shipped in two sizes:

(*a*) *Lump.*—Which shall be of kiln size.

(*b*) *Pulverized.*—Which shall be reduced in size to pass a No. 3 sieve.[2]

Classes. 4. Quicklime is divided into two classes:

(*a*) Calcium;

(*b*) Magnesian.

Basis of Purchase. 5. The particular size and class of quicklime desired shall be specified in advance by the purchaser.

II. SAMPLING.

Lime in Bulk. 6. When quicklime is shipped in bulk, the sample shall be so taken that it will represent an average of all parts of the shipment from top to bottom, and shall not contain a disproportionate share of the top and bottom layers, which are most subject to changes. The samples shall comprise at least 10 shovelsful taken from different parts of the shipment. The total sample taken shall weigh at least 45 kg. (100 lb.) and shall be crushed to pass a 2.54-cm. (1-in.) ring, and quartered to provide a 7-kg. (15-lb.) sample for the laboratory.

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[1] These Tentative Specifications are intended to supersede the Standard Specifications for Quicklime. The Standard Specifications, which were last published under the Serial Designation: C 5-15, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. P. C. Spence, Secretary of Committee C-7 on Lime, 918 G Street, N. W., Washington, D. C.

[2] See specifications for U. S. Standard Sieve Series in a publication now being prepared to supersede Bureau of Standards Circular No. 39.

Lime in Packages. 7. When quicklime is shipped in packages, at least 3 per cent of the number of packages shall be sampled. The packages shall be taken from various parts of the shipment, the samples mixed and the laboratory sample selected as specified in Section 6.

Laboratory Samples. 8. All samples to be sent to the laboratory shall be immediately transferred to an air-tight container in which the unused portion shall be stored until the quicklime shall finally be accepted or rejected by the purchaser.

CHEMICAL PROPERTIES AND TESTS.

Chemical Properties. 9. (*a*) The classes and chemical properties of quicklime shall be determined in accordance with the Tentative Methods of Chemical Analysis of Limestone, Lime and Hydrated Lime (Serial Designation: C 25 – 21 T) of the Americal Society for Testing Materials.[1]

(*b*) Samples shall be taken as specified in Sections 6, 7, and 8.

(*c*) Quicklime shall conform to the following requirements as to chemical composition:

	Calcium Lime.	Magnesian Lime.
Calcium oxide, minimum, per cent	75	..
Magnesium oxide, minimum, per cent	..	20
Calcium and magnesium oxides, minimum, per cent	95	95
Silica, alumina, and oxide of iron, maximum, per cent	5	5
Carbon dioxide, maximum, per cent		
(*a*) If sample is taken at the kiln	3	3
(*b*) If sample is taken at any other place	10	10

All of the above figures are based on the non-volatile portion of the sample.

II. PHYSICAL PROPERTIES AND TESTS.

Percentage of Waste. 10. When tested in accordance with the method given below, quicklime shall be found to contain not more than 3 per cent by weight of waste.

Density. 11. (Specification to be supplied by the committee.)

III. INSPECTION AND REJECTION.

Inspection. 12. (*a*) All quicklime shall be subject to inspection.

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[1] See p. 565.

(*b*) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the quicklime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the quicklime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection.

13. Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within five days from the taking of samples. If the sample is taken at any place other than the place of manufacture, it shall be taken within 24 hours after the receipt of the material.

Rehearing.

14. Samples which represent rejected quicklime shall be preserved in air-tight containers for five days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

IV. METHODS OF TEST.

Percentage of Waste.

15. An average $2\frac{1}{2}$-kg. (5-lb.) sample shall be put in a box and slaked by an experienced operator with sufficient water to produce the maximum quantity of lime putty, care being taken to avoid "burning" or "drowning" the lime. It shall be allowed to stand for 24 hours and then washed through a No. 20 sieve by a stream of water having a moderate pressure. No material shall be rubbed through the screens. The sample of lump lime taken for this test shall be broken so as to all pass a No. 1 sieve and be retained on a No. 3 sieve. Pulverized lime shall be tested as received.

Apparent Density.

16. (Specification to be supplied by the committee.)

APPENDIX.

Quicklime can never be used as such for structural purposes: It must always be slaked first. Since the method of slaking is an important factor in determining the quality of the finished product, the following directions are given, not as a part of the specifications, but as information for the further protection of the purchaser.

PREPARATION OF LIME PUTTY.

Directions for Slaking.

1. (*a*) *Introduction.*—Different kinds of lime vary considerably in the way in which they behave with water. A little supervision over the operation of slaking will amply pay for itself by insuring

the production of the greatest possible quantity and the best possible quality of putty. To find out how to slake a new lot of lime, it is safest to try a little of it and see how it works. Since different lots of the same brand of lime vary somewhat, and since the weather conditions at the time have a decided influence, it is wise to try a sample from each lot used, whether familiar with the brand or not.

(*b*) *Classification of Limes.*—In a bucket, put two or three lumps of lime about the size of one's fist, or, in the case of granular lime, an equivalent amount. Add enough water to just barely cover the lime, and note how long it takes for slaking to begin. Slaking has begun when pieces split off from the lumps or when the lumps crumble. Water of the same temperature should be used for test and field practice.

If slaking begins in less than five minutes, the lime is quick slaking; from five to thirty minutes, medium slaking; over thirty minutes, slow slaking.

(*c*) *Directions for Slaking.*—For quick-slaking lime, always add the lime to the water, not the water to the lime. Have enough water at first to cover all the lime completely. Have a plentiful supply of water available for immediate use—a hose throwing a good stream, if possible. Watch the lime constantly. At the slightest appearance of escaping steam, hoe thoroughly and quickly, and add enough water to stop the steaming. Do not be afraid of using too much water with this kind of lime.

For medium-slaking lime, add the water to the lime. Add enough water so that the lime is about half submerged. Hoe occasionally if steam starts to escape. Add a little water now and then if necessary to prevent the putty from becoming dry and crumbly. Be careful not to add any more water than required, and not too much at a time.

For slow-slaking lime, add enough water to the lime to moisten it thoroughly. Let it alone until the reaction has started. Cautiously add more water, a little at a time, taking care that the mass is not cooled by the fresh water. Do not hoe until the slaking is practically complete. If the weather is very cold, it is preferable to use hot water but if this is not available, the mortar box may be covered in some way to keep the heat in.

Preparation of Putty for Use.

2. (*a*) *White Coat.*—After the action has ceased, run off the putty through a No. 10 sieve and store for a minimum of two weeks.

(*b*) *Base Coats.*—After the action has ceased, run off the putty through a No. 8 sieve. Add sand up to equal parts by weight, all of the hair required, and store for a minimum of two weeks.

(*c*) *Masons' Mortar.*—After the action has ceased, add part or all of the sand required, and store for a minimum of 24 hours.

TENTATIVE SPECIFICATIONS
FOR
HYDRATED LIME FOR STRUCTURAL PURPOSES.[1]

Serial Designation: C 6 - 21 T.

These specifications are issued under the fixed designation C 6; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1917; REVISED, 1919, 1921.

Definition 1. Hydrated lime is a dry flocculent powder, resulting from the hydration of quicklime.

A. MASONS' HYDRATE.

Uses 2. Masons' hydrated lime may be used for scratch or brown coat of plaster, for stucco, for mortars, and for addition to Portland-cement concrete.

I. CHEMICAL PROPERTIES AND TESTS.

Sampling. 3. The sample shall be a fair average of the shipment. Three per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. A $2\frac{1}{2}$-kg. (5-lb.) sample to be sent to the laboratory shall immediately be transferred to an air-tight container, in which the unused portion shall be stored until the shipment has been finally accepted or rejected by the purchaser.

Chemical Properties 4. (*a*) The chemical composition of the hydrated lime shall be determined in accordance with the Tentative Methods of Chemical Analysis of Limestone, Lime and Hydrated Lime (Serial Designation: C 25 - 21 T) of the American Society for Testing Materials.[2]

(*b*) *Carbon Dioxide.*—Carbon dioxide in the sample shall not exceed 5 per cent if the sample is taken at the place of manufacture, or 7 per cent if the sample is taken at any other place. The percentages in both cases are based on the non-volatile portion.

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[1] These Tentative Specifications are intended to supersede the Standard Specifications for Hydrated Lime. The Standard Specifications, which were last published under the Serial Designation: C 6-15, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. P. L. Spence, Secretary of Committee C-7 on Lime, 918 G Street, N. W., Washington, D. C.

[2] See p. 565.

(*c*) *Calcium and Magnesium Oxides.*—Calcium and magnesium oxides shall constitute not less than 95 per cent of the non-volatile portion.

II. PHYSICAL PROPERTIES AND TESTS.

Fineness. 5. A 100-g. sample shall leave a residue of not more than 0.5 per cent on a No. 30 sieve, and not more than 15 per cent on a No. 200 sieve.

Constancy of Volume. 6. A pat of mortar, covered with a skim coat of neat paste, shall be subjected to the action of steam. If the steam has no visible effect on the pat, the sample shall be reported as being "sound." If the pat disintegrates, the sample shall be reported "unsound," and the shipment rejected. If the sample cracks, pops, or shows other minor defects, it shall not be reported as either sound or unsound, but its behavior shall be noted.

Tensile Strength. 7. When tested in the form of a mortar composed of 1 part by weight of the sample and 3 parts by weight of standard Ottawa sand, the mortar shall show a tensile strength of not less than 15 lb. per sq. in. at 7 days.

III. PACKING AND MARKING.

Packing. 8. (*a*) *Kind of Package.*—Hydrated lime may be packed in either cloth or paper bags.

(*b*) *Size of Package.*—The cloth package shall contain 100 lb. net weight of hydrated lime. The paper package shall contain 50 lb. net weight of hydrated lime.

Marking. 9. Each package shall be clearly marked to show the net weight of hydrated lime contained in the package, the name of the manufacturer, the place of manufacture, and the name of the brand.

IV. INSPECTION AND REJECTION.

Inspection. 10. (*a*) All hydrated lime shall be subject to inspection.

(*b*) The manufacturer shall furnish the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hydrated lime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection. 11. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test. If the sample is taken at some place other than the place of manufacture, it shall be taken within 24 hours after receipt of the material.

Rehearing.

12. Samples which represent rejected hydrated lime shall be preserved in air-tight containers for five days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

V. METHODS OF TEST.

Fineness.

13. Fineness[1] of hydrated lime shall be determined as follows:

One hundred grams of the sample as received shall be placed on a No. 30 sieve which shall be nested above a No. 200 sieve. The material shall be washed by means of a stream of water from a faucet (Note 1). The washing shall be continued until the water coming through the sieve is clear. The residue upon the No. 30 sieve shall be dried to constant weight in an atmosphere free from carbon dioxide in a drying oven whose temperature is maintained between 100 and 120° C. The weight of this residue shall be calculated as percentage of the original sample.

The material which has passed the No. 30 sieve and remained on the No. 200 sieve shall be then washed through the latter as above described. The residue on this sieve shall be treated in the same manner as described above for that retained on the No. 30 sieve and the percentage retained added to the percentage of residue on the No. 30 sieve. The sum of these two shall be reported as the percentage of residue on the No. 200 sieve.

NOTE 1.—A small piece of rubber tubing attached to a water faucet will be found convenient. The velocity of the stream of water may be increased by pinching the tubing, but the velocity should not be sufficient to cause any danger of splashing the sample over the sides of the sieve.

Constancy of Volume.

14. Constancy of volume shall be determined as follows:

To 20 g. of the sample, 100 g. of standard Ottawa sand shall be added, mixed thoroughly and enough water added to the mixture to make a good plastic mortar of a rather dry consistency. This shall be spread out on a clean glass plate to form a layer of about 0.5 cm. ($\frac{1}{4}$ in.) thick by about 10 cm. (4 in.) square. The pat shall be of even thickness throughout and not tapering at the edges. If the mortar is too dry to work well, more water may be added. This pat shall be placed in a closet for 24 hours to set. The temperature in the closet shall be between 18 and 24° C. (65 and 75° F.) and there shall be free circulation of air in the closet but no direct draft shall be permitted to hit the pat. At the end of 24 hours the pat shall be removed from the closet and soaked in water until a film of water stands unabsorbed on the surface of the pat. The pat shall be examined carefully for cracks. If any are present, too much water has been used in making the pat and it should be discarded and a new one made.

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[1] Specifications for U. S. Standard Sieve Series in a publication now being prepared to supersede Bureau of Standards Circular No. 39.

Twenty grams of the sample shall be mixed with enough water to form a thick cream. This shall be spread out in a thin layer on the surface of the pat. It shall be allowed to stand for 15 minutes to permit possible air bubbles to form. It shall be troweled to an even surface, making this skim coat as thin as possible without allowing the sand to show through. The pat shall be put back in the closet for another 24 hours for the skim coat to set. It shall be examined carefully to make sure there are no cracks or pops. A vessel shall be provided partially filled with cold water and having a perforated cover. The pat shall be suspended in this vessel in such a way that the water can boil without touching it. The water shall be brought gradually to boiling and kept boiling gently for 5 hours, the pat being surrounded by steam during this time. The water shall then be permitted to cool for at least 12 hours before the cover is removed from the vessel. The pat shall then be removed and examined for cracking, popping, or disintegration.

Tensile Strength.

15. In a suitable vessel, 200 g. of the sample shall be mixed with 600 g. of standard Ottawa sand. Sufficient water shall be added to bring the mixture to the proper consistency which shall be determined as follows:

A clean and well oiled cylindrical mold, 5 cm. (2 in.) in diameter by 10 cm. (4 in.) high, shall be prepared and mounted on a glass plate. This mold shall be filled with the lime mortar and the mold removed immediately by raising it vertically. The mortar is of the proper consistency when the final height of the cylinder, after the mold is removed, is 9 cm. ($3\frac{1}{2}$ in.).

The mixture having been brought to the proper consistency, it shall be molded to form six briquettes. These briquettes shall be of the form and size specified in Section 50 of the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.[1] After the molds have been filled with the mortar, the whole shall be placed in a damp closet and permitted to stand over night. They shall then be removed from the damp closet and permitted to stand exposed to room atmosphere for 24 hours longer. The briquettes shall then be removed from the molds and shall be stored in room atmosphere in such a way that the air can circulate freely around each briquette until ready for test.

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[1] 1921 Book of A.S.T.M. Standards.

For measuring the tensile strength of lime mortars the machine used shall be direct acting; that is, there shall be no levers introduced between the load and the specimen. The cut-off mechanism which stops the application of load shall be automatic and instantaneous. The machine shall be regulated to apply the load at the rate of 15 lb. per minute. The maximum capacity of the machine shall be not less than 50 nor more than 100 lb., and it shall be sensitive to within 1 per cent at any load.

B. FINISHING HYDRATE.

Uses. 16. Finishing hydrated lime may be used for any of the purposes enumerated under masons' hydrate, Section 2, and in addition, it may be used as an ingredient of the final or white coat of plaster.

Properties and Tests. 17. Finishing hydrated lime shall meet all of the chemical and physical requirements given for masons' hydrate, and, in addition, it shall have a plasticity figure of not less than 200, when measured in accordance with Section 20.

Marking. 18. Each package shall be clearly marked to show the net weight of hydrated lime contained therein, the name of the manufacturer, the place of manufacture and the name of the brand. The words "finishing hydrate" may be added.

General Requirements. 19. Except as specified in Sections 16, 17 and 18, all requirements for masons' hydrate shall be equally applicable to finishing hydrate.

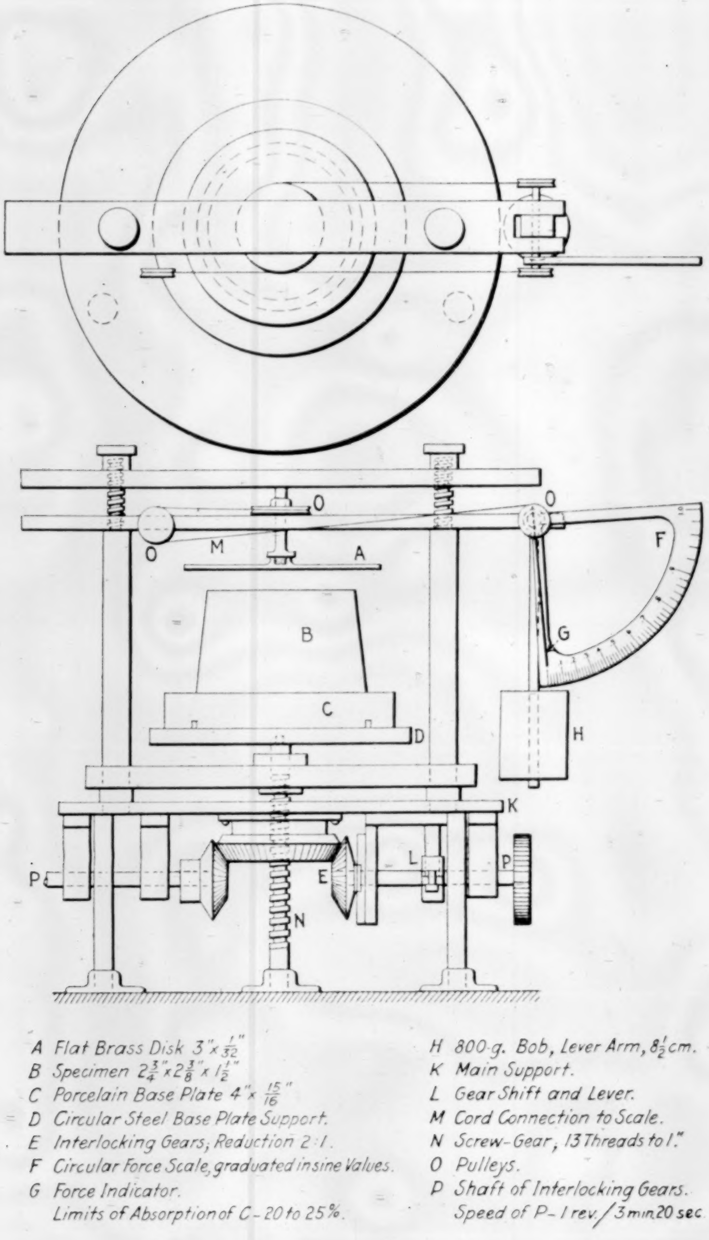
Plasticity. 20. The plasticity shall be determined by means of the apparatus shown in Fig. 1 as follows:

Three hundred grams of the sample shall be mixed with enough water to form a thick paste. This shall be covered with a damp cloth and permitted to stand for 24 hours.

NOTE—It is necessary that the paste be thick enough so that it can be diluted to "normal consistency" by the addition of more water, after standing. The proportion of water will vary with different limes, so that no definite amount can be recommended.

The rubber mold shall be placed on a glass plate and filled with the paste. The mold shall be removed immediately by raising it vertically. The final height of the paste shall be measured. More water shall be added if necessary and the test repeated until the final height of the paste is found to be $1\frac{1}{4}$ in. $\pm \frac{1}{16}$ in. (3.1 cm. ± 1.5 mm.).

The rubber mold shall be placed on a porcelain base plate and filled with the paste, and struck off level. The mold shall be removed by raising it vertically without distorting the paste. The base plate and paste shall be placed in the instrument (Fig. 1) and the carriage



A Flat Brass Disk $3'' \times \frac{1}{32}''$

B Specimen $2\frac{3}{4}'' \times 2\frac{3}{8}'' \times 1\frac{1}{2}''$

C Porcelain Base Plate $4'' \times \frac{15}{16}''$

D Circular Steel Base Plate Support.

E Interlocking Gears; Reduction 2 : 1.

F Circular Force Scale, graduated in sine Values.

G Force Indicator.

Limits of Absorption of C - 20 to 25%.

H 800-g. Bob, Lever Arm, $8\frac{1}{2}$ cm.

K Main Support.

L Gear Shift and Lever.

M Cord Connection to Scale.

N Screw-Gear, 13 Threads to 1."

O Pulleys.

P Shaft of Interlocking Gears.

Speed of P - 1 rev./3 min. 20 sec.

FIG. 1.—Emley Plasticimeter.

turned up by hand until the surface of the paste comes in contact with the disk.

NOTE—Evidence of this contact is given by the tautness of the string which connects the disk to the bob.

The carriage shall be thrown into gear and the motor started. It is essential that the motor shall be started exactly sixty seconds after the first portion of paste has been put in the mold. The time when the first portion of paste is put in the mold shall be recorded as zero time—the motor therefore is started at one minute.

The position of the bob shall be read and recorded every 15 seconds until the experiment is complete.

The experiment shall be considered complete when (*a*) the bob runs off the scale; (*b*) any reading is less than the one before, indicating that the bob has fallen back; or (*c*) the bob has remained stationary for four consecutive readings (one minute) and the specimen has either visibly ruptured or broken loose from the base plate.

The time and the position of the bob at the end of the experiment shall be noted. The time, in minutes, elapsed since zero time shall be called T and the position of the bob (indicating the force) F.

After the experiment is complete, the material shall be put back with the rest of the paste, mixed and allowed to stand until 28 hours old. Enough water shall be added to bring the mixture to normal consistency and the experiment repeated. The same material shall again be tested when 48 hours old. The three readings for T and F shall be averaged and the average values used in the following calculations.

The plasticity figure, P, shall be calculated from the formula:

$$P = \sqrt{F^2 + (10\ T)^2}.$$

For a finishing hydrate, this figure shall be not less than 200.

The angle shall be determined whose tangent is $\frac{F}{10\ T}$. If this angle is less than 45 deg. the hydrate is sandy, or free working; if greater than 45 deg. it is sticky, and tends to follow the trowel. This angle is calculated for information only, and shall not be used in the specification.

NOTE.—The plasticity of hydrated lime changes more or less when the material is soaked. By averaging three determinations on the same material at different specified times, it is felt that this effect is included in the results.

TENTATIVE SPECIFICATIONS
FOR
CONCRETE AGGREGATES.[1]

Serial Designation: C 33 – 21 T.

These specifications are issued under the fixed designation C 33; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

FINE AGGREGATE.

Fine Aggregate. 1. Fine aggregate shall consist of sand, stone screenings, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable uncoated grains, free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances.

Grading. 2. Fine aggregate shall preferably be graded from fine to coarse, with the coarser particles predominating, within the following limits:

Passing No. 4 sieve	100 per cent
Passing No. 50 sieve, not more than	30 "
Weight removed by elutriation test, not more than	3 "

Sieves shall conform to the requirements specified in the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41 – 21T) of the American Society for Testing Materials.[2]

Strength in Concrete. 3. The fine aggregate shall be tested in combination with the coarse aggregate and the cement with which it is to be used and in the proportions, including water, in which they are to be used on the work, in accordance with the requirements specified in Section 6. In case the test provided in Section 6 shows the strengths specified therein, the fine aggregate shall be considered acceptable.

Mortar Strength. 4. With the approval and consent of the engineer, on less important work, the following requirements may be substituted:

(*a*) Mortar briquettes, cylinders or prisms, consisting of one part by weight of Portland cement and three parts by weight[3] of fine aggregate, mixed and tested in accordance with the methods described in the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials,[1] shall show a tensile or compressive strength at the age of 7 and 28 days not less than that of 1 : 3 standard Ottawa sand mortar of the same consistency made with the same cement.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. J. C. Pearson, Secretary of Committee C-9 on Concrete and Concrete Aggregates, Bureau of Standards, Washington, D. C.

[2] See p. 586.

[3] When approved by the engineer these proportions may be by volume, assuming one cubic foot of cement to weigh 94 lb.

NOTE.—In testing aggregates, care should be exercised to avoid the removal of any coating on the grains which may affect the strength; bank sand should not be dried before being made into mortar, but should contain natural moisture. The percentage of moisture may be determined upon a separate sample and the weight of the sand used in the test corrected for the moisture content.

(*b*) Upon failure to meet this requirement, the proportion of cement in the concrete mixture shall be increased or the proportions of cement, fine aggregate, coarse aggregate and water changed in such a way as to produce the strength specified in Section 6.

Colorimetric Test.

5. No fine aggregate showing a color darker than the standard color when tested in accordance with the Tentative Method of Test for Organic Impurities in Sands for Concrete (Serial Designation: C 40 - 21T) of the American Society for Testing Materials[2] shall be used unless the strength requirement of Section 6 is fulfilled.

Concrete Tests.

6. The grade of concrete required with its compressive strength in pounds per square inch shall be specified by the engineer. The concrete materials, including cement, fine aggregate, coarse aggregate and water, mixed in the proportions in which they are to be used in the work, and tested in accordance with the standard methods of test, shall at 28 days develop a strength of not less than that specified for the grade of concrete required. Upon failure to meet this requirement the proportion of cement in the concrete mix shall be increased or the proportions of cement, fine aggregate, coarse aggregate and water shall be changed in such way as to produce the specified strength.

COARSE AGGREGATE.

Coarse Aggregate.

7. Coarse aggregate shall consist of crushed stone, gravel, or other approved inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated pieces free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

Grading of Coarse Aggregate.

8. (*a*) Coarse aggregates shall be well graded from fine to coarse within the following limits:[3]

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[1] 1921 Book of A.S.T.M. Standards.

[2] See p. 585.

[3] When there are several suitable aggregates available, a thorough investigation of the relative economy of each for producing concrete of the desired strength is advisable, especially for work of considerable magnitude.

Passing — in. sieve (maximum size) .... 100 per cent
Passing — in. sieve (intermediate size) .... —to — "

Not more than 15 per cent shall pass the No. 4 sieve, not more than 5 per cent shall pass a No. 8 sieve.

(*b*) The maximum size of coarse aggregate shall be either designated by the engineer or indicated on the plans.

NOTE.—The grading as above specified is intended to secure uniformity of aggregate, but will be governed by local conditions. The following table indicates desirable gradings, in percentages, for coarse aggregate for certain maximum sizes:

Maximum Size of Aggregate, in.	Circular Openings, in.								Passing Screen having Circular Openings $\frac{1}{4}$ in. in Diameter, not more than
	3	$2\frac{1}{2}$	2	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$	
3................	100	...	...	40-75	...	...	...	...	15 per cent
$2\frac{1}{2}$..............	...	100	...	...	40-75	...	...	...	15 "
2................	...	...	100	...	...	40-75	...	...	15 "
$1\frac{1}{2}$..............	...	...	...	100	...	...	40-75	...	15 "
$1\frac{1}{4}$..............	...	...	...	...	100	...	...	35-70	15 "
1................	...	...	...	...	...	100	...	40-75	15 "
$\frac{3}{4}$..............	...	...	...	...	...	...	100	...	15 "

NOTE.—These specifications were formulated in conference with members of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete.

TENTATIVE SPECIFICATIONS

FOR

CLAY HOLLOW BUILDING TILE.[1]

Serial Designation: C 34 - 21 T.

These specifications are issued under the fixed designation C 34; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

I. MATERIALS AND MANUFACTURE.

Process.

1. These specifications cover load-bearing hollow tile made from surface clay, shale or fire clay or a combination of any of these materials. The raw material, in plastic form, is forced through a die, the resulting hollow stream of plastic material being cut to suitable lengths and afterward dried and burned to give the product strength and permanence.

II. PHYSICAL PROPERTIES AND TESTS.

(*A*) *Physical Test Requirements.*[2]

Compression Test.

2. (*a*) The average ultimate compressive strength for hollow building tile which is designed to be used with the cells vertical, and when tested in that position, shall be not less than 1500 lb. per sq. in. of the nominal gross area of the bearing face.

(*b*) The average ultimate compressive strength for hollow building tile which is designed to be used with the cells horizontal, and when tested in that position, shall be not less than 700 lb. per sq. in. of the nominal gross area of the bearing face.

Freezing Test.

3. Samples representing tile that is to be used for foundations or for exterior walls shall endure 30 alternate freezings and thawings without failure, as defined in Section 23.

Fire Test.

4. Tile on which fire tests are made shall meet the requirements of the Standard Specifications for Fire Tests of Materials and Construction (Serial Designation: C-19) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. C. Crockatt, Secretary of Committee C-10 on Hollow Building Tile, The Hollow Building Tile Association, Conway Building, Chicago, Ill.

[2] Tests now under way may result in the modification of the physical test requirements here given, and until further data are available they should be taken as strictly tentative.

[3] 1921 Book of A.S.T.M. Standards.

(*B*) *Selection of Samples for Test.*

Testing Operator. 5. All tests shall be made by competent experienced operators in recognized testing laboratories.

Selection of Samples for Test. 6. Specimens of tile for test shall be selected by the purchaser or by a competent representative authorized by him to do this work. In all cases, the samples shall be fairly representative of the whole lot of tile from which they are selected. Full size tile shall be taken in all cases.

Number of Samples. 7. For the strength test five individual tile shall be selected. Five tile shall be selected for the freezing test. For the fire test, the size of the fire test specimen will govern the number of tile required.

Time and Place of Selection of Samples. 8. Samples for strength test shall be selected at the factory or at the point of delivery, as specified in the sales contract. If the freezing test or the fire test, or both, is to be made, it shall be so specified at the time of placing the order; samples for these tests shall be selected at the factory, at least 45 days in advance of the time of shipment.

Marking Samples. 9. All tile selected for test shall be plainly and permanently marked for reference by the testing operator.

(*C*) *Strength Tests.*

Testing Machine. 10. Any recognized type of compression testing machine may be employed.

Speed of Testing Machine. 11. The speed of the moving head shall be not more than 0.05 in. per minute.

Spherical Bearing Block. 12. A spherical bearing block of a type in common use in testing practice shall be used. It shall be placed on the top of the test specimen.

Capping. 13. Bearing surfaces of the test specimens and portions adjoining them which are liable to absorb water from the plastic capping which is to be applied later shall be coated with one good coat of liquid shellac and allowed to dry. They shall then be "buttered" with a plastic mortar of calcined gypsum (plaster of Paris) tempered with water to give a consistency slightly exceeding the normal. The specimen shall be given a single firm pressure upon a smooth plane surface of steel or plate glass which has been moderately oiled, and left for the capping to set. The thickness of the cap after the extruded plaster has been removed and the edges trued should be found uniform and not to exceed $\frac{1}{8}$ in. "Patching" of caps after setting shall not be permitted and imperfect caps shall be replaced.

14. Tile may be tested as soon as the plaster cap has well set but not sooner than 30 minutes after the specimens have been removed from the plates. **Time of Testing.**

15. Tile shall be tested in the position in which they are designed to be used—vertical or horizontal. **Position of Tile in Testing Machine.**

16. All tile shall be tested to failure. **Maximum Load.**

17. The results of the tests shall be reported separately for each of the five individual sample tile constituting a standard test, together with the average, in the form given in Table I. **Reporting the Test Results.**

TABLE I.—DATA SHEET FOR HOLLOW TILE MATERIAL.

Date..

Location of testing..

Manufacturer..

At..

Test made by..

For use in..

Specimen Number.	Sketch of Tile.	Nominal Size of Tile.	Position in which Tested.	Color of Tile.	Weight.	Maximum Load.	
						Lb.	Lb. per sq. in of Nominal Gross Area.

(D) *Freezing Tests.*

18. Test specimens for the freezing test shall be sawed from unbroken tile. Three specimens shall be taken from each of the five sample tile. Two of the test specimens from each tile shall be obtained from opposite outer walls of the tile and the third from the web section. **Test Specimens.**

They shall be approximately square and between 12 and 20 sq. in. in area.

19. Preparatory to the freezing test, all specimens shall be dried in a drier or oven at a temperature of not less than 110° C. (230° F.) for not less than three hours, or to constant weight. **Drying the Test Specimens.**

20. The balance used shall be sensitive to 0.5 g. when loaded with one kilogram and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same order of accuracy shall be obtained. **Accuracy of Weighings.**

21. The specimens shall be immersed for 72 hours in water having a temperature of 14 to 24° C. (65 to 75° F.) and then weighed. **Obtaining the Wet Weight.**

In re-weighing after immersion, the specimens shall be removed from the water, allowed to drain for not more than one minute and the superficial water removed by a towel or blotting paper, after which they shall be weighed immediately.

Freezing and Thawing.

22. When the specimens have been weighed after saturation with water, they shall be returned to the water, and kept immersed till the freezing test is begun. For freezing, they shall be placed on edge in water-tight metal trays, suitably mounted in a rigid metal crate, and immersed in ice water until the specimens have attained substantially the temperature of the water, after which the water shall be drawn down to a depth of ½ in. in each tray. The crate shall then be lifted as a whole, without disturbing the specimens, and placed in the freezing apparatus.

Freezing shall be performed in a quiet atmosphere, free from perceptible natural or artificial currents. If artificial freezing apparatus is employed, the apparatus shall have sufficient heat-absorbent capacity to enable the temperature of the freezing chamber to be brought to −10° C. (+14° F.) or below, within 30 minutes after the introduction of the specimens. The temperature in the freezing apparatus shall not fall lower than −20° C. (−4° F.). The freezing shall be continued until the water in the trays is frozen solid. Exposure to freezing conditions in excess of this requirement shall be considered as without significance.

At the conclusion of the freezing under the specified conditions, the crate of specimens shall be withdrawn and at once immersed in water at a temperature of 18 to 24° C. (65 to 75° F.) in a special receptacle of proper size. Heating shall be continued so that the water will regain the required temperature as soon as practicable after the specimens are immersed. A temperature of 18 to 24° C. (65 to 75° F.) shall then be maintained for not less than 2 hours. At the conclusion of the thawing treatment, the crate of specimens shall be inspected and the condition of each sample after each thawing shall be noted in the records.

Determining Failure in Freezing and Thawing Tests.

23. Failure under the freezing and thawing treatment shall be considered to be reached when:

(*a*) The specimens show superficial disintegration or spalling with loss of weight of more than 5 per cent of the initial dry weight; or,

(*b*) The specimens are badly cracked; or,

(*c*) The specimens show evident serious loss of structural strength.

(*E*) *Tolerances.*

Failure of Individual Tile.

24. The failure of individual tile to meet the strength requirement shall not consitute cause for rejection, provided:

(*a*) The average strength for the entire lot tested shall not be lower than the specified strength.

(*b*) Not more than one of the five tile tested shall give a test result lower than 80 per cent of the strength specified.

Sorting and Selection of New Samples.

25. In case any lot of tile shall fail to meet the strength requirement, the shipper shall have the privilege of sorting the tile and removing those which appear to be inferior, after which new samples shall be selected, as before, except that ten shall be selected instead of five. The ten new samples shall be tested and the same tolerance observed as specified in Section 24, two out of ten tile being allowed to fall below the 80-per-cent mark instead of one out of five.

TABLE II.—WEIGHTS, SIZES AND DIMENSIONS OF STANDARD LOAD-BEARING TILE.

Dimensions, in.	Number of Cells.	Scoring Depth, in.	Scoring Spacing, in.	Standard Weight, lb.	Minimum Weight, lb.
Backing-up Tile:					
4 by 5 by 12	1	$\frac{1}{8}$	1	9	8
8 by 5 by 12	2	$\frac{1}{8}$	1	15	14
8 by 5 by 12	3	$\frac{1}{8}$	1	17	16
Load-Bearing Wall Tile:					
3 by 12 by 12	3	$\frac{1}{4}$	2	18	17
4 by 12 by 12	3	$\frac{1}{4}$	2	20	19
6 by 12 by 12	6	$\frac{1}{4}$	2	30	28
8 by 12 by 12	6	$\frac{1}{4}$	2	36	34
10 by 12 by 12	6	$\frac{1}{4}$	2	42	40
12 by 12 by 12	6	$\frac{1}{4}$	2	48	46
Slabs	..	optional	optional	1 lb. per 1 in. of width	

Rejection under Strength Requirement.

26. Failure of the samples selected after sorting, to meet the test requirement, with the tolerance given, shall constitute cause for rejection of the entire lot.

Failure of Individual Test Specimens in Freezing Test.

27. Except in those cases in which it is specified, at the time of placing the order, that the tile are to be used for foundation work, failure of individual test specimens in the freezing test shall not constitute cause for rejection, provided not more than 20 per cent of the test specimens shall fail in this test.

III. STANDARD SIZES AND DIMENSIONS.

Minimum Net Sectional Areas. 28. In all tile, the net area of the cross-section taken in a plane parallel to the ends of the tile shall be not less than 45 per cent of the gross area of the same section.

Tolerances in Dimensions. 29. No dimension shall be more than 4 per cent under nor 2 per cent over the dimensions given in Table II for standard tile, or from the dimensions ordinarily recognized as standard for any other form of tile.

Minimum Weights. 30. The weight of tile of standard size shall not be less than the minimum weights given in Table II.

IV. WORKMANSHIP AND FINISH.

Defects. 31. All tile shall be free from such cracks, blisters, surface roughness and other defects as would evidently interfere with the proper setting of the tile or impair their strength or permanence.

Scoring. 32. The external surface of all tile intended for mortar or stucco shall be scored in such a manner as to give good anchorage for mortar or plaster. The standard scoring given in Table II is recommended.

V. MARKING.

Marking. 33. All tile conforming to the design requirements of this specification shall bear the initials, name or trademark of the manufacturer. These marks shall be indented on the exterior of the tile and shall be plainly legible.

VI. INSPECTION AND REJECTION.

Inspection for Requirement not Covered by Tests. 34. Inspection for weight, size, sectional area, workmanship and finish shall be made by a competent inspector employed by the purchaser or builder. Such inspection shall be made at the factory or at point of delivery according to agreement between purchaser and shipper.

Rejections. 35. Individual tile shall be rejected for failure to comply with the foregoing specifications covering these points. In case more than 25 per cent of a shipment shall fail to comply with these specifications, the purchaser may reject the entire shipment.

Expense of Tests. 36. Selection of samples, testing and inspection shall be paid for by the purchaser.

Facilities for Inspection. 37. The shipper shall afford the inspector all reasonable facilities for his work. This applies to both the selection of test samples and the visual inspection. All inspections shall be made within a reasonable time.

Rejected Tile. 38. The inspector shall mark plainly all tile which he rejects and such rejected material shall be removed promptly by the shipper or his agent.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM.[1]

Serial Designation: C 22 – 21 T.

These specifications are issued under the fixed designation C 22; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1919; REVISED, 1920, 1921.

I. MATERIALS AND STANDARDS.

Testing. 1. The chemical and physical properties of gypsum shall be determined in accordance with the Tentative Methods of Testing Gypsum and Gypsum Products (Serial Designation: C 26–21 T) of the American Society for Testing Materials.[2]

Definition. 2. (*a*) Pure gypsum is calcium sulfate combined in crystallin form with two molecules of water.

(*b*) Its chemical formula is $CaSO_4 \cdot 2H_2O$.

(*c*) No material may be considered gypsum within the meaning of these specifications which contains more than 35.5 per cent by weight of impurities.

Forms and Sizes. 3. Gypsum may be marketed in any of the following forms and sizes:

(*a*) *Run-of-Mine.*—The form in which it comes from the mine or quarry.

(*b*) *Crushed.*—Run-of-mine gypsum further reduced to sizes suitable for specific uses. Crushed gypsum may be marketed in either of the following sizes:

> No. 1.—Material of this size shall all pass through a 3-in (7.6-cm.) ring; not more than 30 per cent shall pass through a 100-mesh screen, and not less than 40 per cent shall be retained on a $\frac{3}{16}$-in. (0.469-cm.) or equal mesh screen.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

[2] See p. 590.

No. 2.—Material of this size shall pass through a 2-in. (5.08-cm.) ring; not more than 30 per cent shall pass through a 100-mesh screen, and not less than 10 per cent shall be retained on a $\frac{3}{16}$-in. (0.469-cm.) or equal mesh screen.

(c) *Ground.*—Crushed gypsum further reduced to sizes suitable for specific uses. Ground gypsum may be marketed in any of the following sizes:

No. 1.—Material of this size shall all pass a 14-mesh sieve, and not less than 85 per cent of it shall pass a 100-mesh sieve.

No. 2.—Material of this size shall all pass a 14-mesh sieve, and not less than 60 nor more than 85 per cent of it shall pass a 100-mesh sieve.

No. 3.—Material of this size shall all pass an 8-mesh sieve, and not less than 40 nor more than 60 per cent of it shall pass a 100-mesh sieve.

Chemical Properties.

4. The chemical composition, within the limits prescribed by Section 2, shall be a matter of contract.

II. SAMPLING.

Sampling from Bulk.

5. When gypsum is shipped in bulk, samples of about 5 lb. (2.25 kg.) each shall be taken at regular intervals during the complete loading or unloading of the carrier, in such a way as to accumulate at least 200 lb. (90 kg.) of material. This shall be broken so that it will all pass a 1-in. (2.5-cm.) ring, thoroughly mixed, and reduced by quartering to provide not less than a 1-lb. (0.5-kg.) sample for the laboratory.

Sampling from Packages.

6. When gypsum is shipped in packages, at least 3 per cent of the packages shall be sampled. Samples shall be taken from both the surface and the center of the packages. These samples shall then be broken, mixed, and quartered as directed above.

Laboratory Samples.

7. All laboratory samples shall be placed immediately in an air-tight container and shipped to the laboratory for test.

III. PACKING AND MARKING.

Packing and Marking.

8. (*a*) Gypsum may be shipped either in packages or in bulk.

(*b*) When shipped in packages for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of manufacturer;
Form and size of material;
Chemical analysis of the material, giving the minimum percentages of CaO and SO_3;
Net weight of package.

(*c*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

IV. INSPECTION AND REJECTION.

Inspection. 9. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection. 10. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications, and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing. 11. Claims for rehearing shall be valid only if made within 20 working days from receipt of notice of specific cause for rejection.

TENTATIVE SPECIFICATIONS
FOR
CALCINED GYPSUM.[1]

Serial Designation: C 23 - 21 T.

These specifications are issued under the fixed designation C 23; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1919; REVISED, 1920, 1921.

I. MATERIALS AND STANDARDS.

Testing. 1. The chemical and physical properties of calcined gypsum shall be determined in accordance with the Tentative Methods of Testing Gypsum and Gypsum Products (Serial Designation: C 26 - 21 T) of the American Society for Testing Materials.[2]

Definition. 2. Calcined gypsum is the product resulting from the partial dehydration of gypsum by means of heat.

Sizes. 3. Calcined gypsum may be marketed in either of the following sizes:

No. 1.—Material of this size shall all pass a 14-mesh sieve, and not less than 75 per cent of it shall pass a 100-mesh sieve.

No. 2.—Material of this size shall all pass a 14-mesh sieve, and not less than 40 nor more than 75 per cent of it shall pass a 100-mesh sieve.

NOTE.—A tolerance provision of 1 per cent on all sieve determinations is permitted.

Fineness. 4. (*a*) Calcined gypsum may be marketed in any of the sizes enumerated for calcined gypsum in Section 3. Each package or each shipment, shipped for resale, shall be accompanied by a tag or card which shall contain the information required by Section 12.

(*b*) Calcined gypsum for molding or casting shall all pass a 14-mesh sieve and not less than 75 per cent of it shall pass a 100-mesh sieve.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

[2] See p. 590

5. Specification to be supplied by the committee when the information is available. **Color.**

6. Specification to be supplied by the committee when the information is available. **Plasticity.**

7. (*a*) The time of set of calcined gypsum shall be suitable for the purposes intended, and shall conform to the provisions prescribed for such in the Standard Specifications for Gypsum Plasters (Serial Designation: C 28) of the American Society for Testing Materials.[1] **Time of Setting.**

(*b*) Calcined gypsum for molding or casting shall set in not less than 10 minutes nor more than 40 minutes.

8. (*a*) Calcined gypsum shall have a tensile strength of not less than 200 lb. per sq. in. (14 kg. per sq. cm.). **Tensile Strength.**

(*b*) Calcined gypsum for molding or casting shall have a tensile strength of not less than 200 lb. per sq. in. (14 kg. per sq. cm.).

9. (*a*) Calcined gypsum shall have a compressive strength of not less than 1000 lb. per sq. in. (70 kg. per sq. cm.). **Compressive Strength.**

(*b*) Calcined gypsum for molding or casting shall have a compressive strength of not less than 1000 lb. per sq. in. (70 kg. per sq. cm.).

II. SAMPLING.

10. At least 3 per cent of the packages shall be sampled, and shall be so selected as to be representative of the contents of the shipment. Samples shall be taken from both the surface and the center of the packages. The material so obtained shall be thoroughly mixed and reduced by quartering to provide not less than a 15-lb. (6.75 kg.) sample for the laboratory. **Sampling.**

11. All laboratory samples shall immediately be placed in an air-tight container and shipped to the laboratory for test. **Laboratory Samples.**

III. PACKING AND MARKING.

12. Calcined gypsum may be shipped in either packages or in bulk. **Packing and Marking.**

(*a*) When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of manufacturer;
Brand;
Description;
Net weight of package.

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[1] 1921 Book of A.S.T.M. Standards.

(*b*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

IV. INSPECTION AND REJECTION.

Inspection. 13. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection. 14. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing. 15. Claims for rehearing shall be valid only if made within 20 working days from receipt of notice of specific cause for rejection.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM PLASTERING SAND.[1]

Serial Designation: C 35 - 21 T.

These specifications are issued under the fixed designation C 35; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

1. (*a*) Sand used for plastering purposes in which a gypsum plaster is employed shall be free from salt and from alkaline, organic or other deleterious substances. **Quality.**

(*b*) It shall be graded from fine to coarse, and when dry not more than 10 per cent by weight shall be retained on a No. 8 sieve; not less than 80 per cent by weight shall be retained on a No. 50 sieve; and not more than 6 per cent by weight shall pass a No. 100 sieve. These sieves shall meet the specifications given in the Bureau of Standards' Standard Screen Scale.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM WALL BOARD.[1]

Serial Designation: C 36 - 21 T.

These specifications are issued under the fixed designation C 36; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Definition. 1. Gypsum wall boards are attached to structural supporting members and constitute finished wall, ceiling and partition surfaces in the interior of buildings, and are suitable to further decorative treatment.

Composition. 2. Gypsum wall boards shall consist of sheets or slabs composed of one layer of hydrated calcined gypsum, with or without fiber, reinforced on the surfaces with a covering made from chip, pulp, or news stock.

Thickness. 3. Gypsum boards shall be $\frac{3}{8}$ in. (9.5 mm.) thick with permissible local variations of $\pm\frac{1}{32}$ in. (0.8 mm.).

NOTE.—Gypsum wall boards are manufactured in thicknesses from $\frac{1}{4}$ in. (6.3 mm.) to $\frac{1}{2}$ in. (12.7 mm.) with permissible local variations of $\pm\frac{1}{32}$ in. (0.8 mm.) from the nominal thickness.

Dimensions. 4. Where gypsum wall boards are to be laid with the joints butted, the widths shall be 32 in. (81 cm.), 36 in. (91 cm.) and 48 in., (122 cm.) with a permissible variation of $\pm\frac{3}{32}$ in. (2 mm.). Where the joints are to be filled with a joint filler, the widths shall be about $\frac{1}{4}$ in. (6.3 mm.) less than those stated, with the same permissible variations. The lengths shall be 4 ft. (122 cm.), 5 ft. (152 cm.), 6 ft. (183 cm.), 7 ft. (213 cm.), 8 ft. (244 cm.), 9 ft. (274 cm.), and 10 ft. (304 cm.), with permissible variations of $\pm\frac{3}{8}$ in. (9.5 mm.).

Weight. 5. The weight of gypsum wall board shall be not less than 1500 lb. (680 kg.) nor more than 2000 lb. (907 kg.) per 1000 sq. ft.

Strength. 6. (*a*) Strength test specimens shall be 12 in. (30 cm.) wide and approximately 18 in. (46 cm.) long, and when tested shall be supported on parallel knife-edge bearings spaced 16 in. (41 cm.) apart, and shall be loaded through a similar bearing midway between the supports.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

(*b*) When tested as described, specimens taken from the gypsum wall boards shall carry a load of not less than 60 lb. (27.22 kg.) when the knife edges are across the fiber of the surfacing, and not less than 32 lb. (14.51 kg.) when the knife edges are parallel to the fiber of the surfacing.

(*c*) Samples tested shall fail by rupture of the surfacing and core and not by the breaking of the bond between the surfacing and the core.

Finish. 7. That surface of the gypsum wall board designed to be exposed on erection shall be true and free from imperfections that would render the wall boards unfit for use with or without decorations. The edges and ends shall be straight and solid. Where the boards are to be butted, the corners shall be square with both side edges. Where the joints are to be filled, the corners shall be square with a permissible variation of $\frac{1}{8}$ in. (3 mm.) in the full width of the wall board.

Sampling. 8. At least one per cent of the number of gypsum wall boards in a shipment shall be so selected as to be representative of the contents. Twenty-five per cent of such selected samples, but not to exceed five individual boards, shall constitute the number required for test purposes.

Packing and Marking. 9. (*a*) Gypsum wall boards shall be shipped so as to be kept dry and free from injury.

(*b*) When shipped for resale, the following information shall be legibly marked, or pasted, upon each board:

Name of Manufacturer;
Brand.

Inspection. 10. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection. 11. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these specifications and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing. 12. Claims for rehearing shall be valid only if made within twenty working days from receipt of notice of specific cause for rejection.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM PLASTER BOARD.[1]

Serial Designation: C 37 – 21 T.

These specifications are issued under the fixed designation C 37; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Definition. 1. Gypsum plaster boards are a lath or backing for the application of gypsum plaster upon the walls, ceilings and partitions in the interior of buildings.

Composition. 2. Gypsum plaster boards shall consist either of sheets or slabs composed of one or more layers of hydrated calcined gypsum, with or without fiber, reinforced on the surfaces with a covering made from pulp, news or felt stock; or of sheets or slabs composed of an intimate mixture of hydrated calcined gypsum and fibrous binding material.

Thickness 3. Gypsum plaster boards shall be not less than $\frac{1}{4}$ in. (6.3 mm.) nor more than 1 in. (25 mm.) thick, with permissible local variations of not more than $\pm\frac{1}{16}$ in. (1.6 mm.) from the nominal thicknesses.

Dimensions. 4. The nominal width of gypsum plaster boards is usually 32 in. (81 cm.), and the nominal length 24 in. (61 cm.), 36 in. (91 cm.) or 48 in. (122 cm.).

Weight. 5. The weight of gypsum plaster board per 1000 sq. ft. shall conform to the following:

THICKNESS,		WEIGHT, MINIMUM.		WEIGHT, MAXIMUM.	
IN.	MM.	LB.	KG.	LB.	KG.
$\frac{1}{4}$	6.3	1200	544	1500	680
$\frac{5}{16}$	8	1250	567	1650	750
$\frac{3}{8}$	9.5	1500	680	2000	907
$\frac{1}{2}$	12.7	2000	907	3000	1361
1	25	4500	2041	5500	2495

Strength. 6. (*a*) Strength test specimens shall be 12 in. (30 cm.) wide and approximately 18 in. (46 cm.) long, and when tested shall be supported on parallel knife-edge bearings spaced 16 in. (41 cm.) apart, and shall be loaded through a similar bearing midway between the supports.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

(*b*) When tested as described, specimens taken from the gypsum plaster boards shall carry not less than the following loads:

BOARD THICKNESS, IN.	LOAD, LB.	
	KNIFE EDGES ACROSS FIBER OF SURFACING.	KNIFE EDGES PARALLEL TO FIBER OF SURFACING.
$\frac{3}{8}$	40	20
$\frac{5}{16}$	35	17
$\frac{1}{4}$	30	14

(*c*) Samples tested shall fail by rupture of the surfacing and core and not by the breaking of the bond between the surfacing and the core.

(*d*) Gypsum plaster boards which are of a thickness greater than $\frac{3}{8}$ in. (9.5 mm.), or which are not reinforced on the surfaces with a covering made from chip, pulp, news or felt stock, shall conform to all of the requirements of these specifications for a gypsum plaster board $\frac{3}{8}$ in. (9.5 mm.) in thickness.

Finish.

7. The surfaces shall be such that they will readily receive and retain gypsum plaster. The edges and ends shall be reasonably straight and solid. The corners shall be square with a permissible variation of $\frac{1}{4}$ in. (6 mm.) in the full width of the plaster boards. Gypsum plaster boards shall be free from cracks and imperfections that will render them unfit for use.

NOTE.—Gypsum plaster boards that have their corners blurred or broken shall be considered acceptable, provided that the broken portion is not more than $1\frac{1}{2}$ in. (38 mm.) in length.

Sampling.

8. At least one per cent of the number of gypsum plaster boards in a shipment shall be so selected as to be representative of the contents. Twenty-five per cent of such selected samples, but not to exceed ten individual boards, shall constitute the number required for test purposes.

Packing and Marking.

9. (*a*) Gypsum plaster boards shall be shipped so as to be kept dry and free from injury.

(*b*) When shipped for resale the following information shall be legibly marked, or pasted, upon each board:

Name of manufacturer;
Brand.

Inspection.

10. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser

shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection. 11. Any rejection shall be based upon the specific cause of failure to conform to the requirements of these sepecifications, and shall be reported within ten working days from the receipt of the shipment by the consignee.

Rehearing. 12. Claims for rehearing shall be valid only if made within twenty working days from receipt of notice of specific cause for rejection.

TENTATIVE METHODS OF CHEMICAL ANALYSIS
OF
LIMESTONE, LIME AND HYDRATED LIME.[1]

Serial Designation: C 25 – 21 T.

These methods are issued under the fixed designation C 25; the final number indicates the year of original issue, or in case of revision, the year of last revision.

Issued, 1919; Revised, 1921.

Treatment of Sample

Treatment of Sample.

The sample, taken and prepared in accordance with the requirements of the particular specifications of the Society applicable to the material shall be treated as follows:

Weigh out 0.5 g. of the substance and, if a limestone or hydrated lime, ignite in a covered platinum crucible in an electric muffle (Note 1) for 15 minutes, or longer if the heat is not powerful enough to effect complete decomposition within that time. Transfer to an evaporating dish, preferably of platinum (Note 2) for the sake of celerity in evaporation, mix to a thin slurry with distilled water, add 5 to 10 cc. of HCl (sp. gr. 1.20) and digest with aid of gentle heat and agitation until solution is complete. Solution may be aided and the time shortened by light pressure with the flattened end of a glass rod upon resistant lumps. Then evaporate the solution to dryness, so far as this may be possible on the water bath.

DETERMINATION OF SILICA.

Silica.

When dry or nearly so, place the dish and its contents in an air bath or (covered) on a platinum triangle resting on a hot plate and, if it is a high calcium limestone that is under treatment, heat for one hour at 200° C.; if a high magnesian stone is under treatment the temperature should not exceed 120° C. Drench the cooled mass with HCl (sp. gr. 1.20) and allow to stand for a few minutes. Add an equal volume of water, cover the dish and place on the water bath for

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[1] *Bulletin 700*, U. S. Geological Survey, should be used as a reference book in connection with these methods, especially when very exact and detailed analyses are desired. Blank determinations should be made on all reagents, and corrections applied when called for.

Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. P. C. Spence, Secretary of Committee C-7 on Lime, 918 G Street, N. W., Washington, D. C.

10 minutes (Note 3). Separate the silica by filtration on a filter of suitable size. Wash thoroughly with dilute HCl and then wash twice with cold water.

Evaporate the filtrate to dryness. Extract the residue with HCl as before but allowing only a few minutes time. Filter this solution through a second and smaller paper.

Transfer, wet, the papers containing the separated residue to a weighed platinum crucible. Char carefully without allowing the paper to inflame and ignite to constant weight in an electric muffle and weigh (Note 1). Correct the weighed silica for foreign matter by evaporating with 5 cc. of HF and one or two drops of H_2SO_4.[1] Heat the residue for 2 or 3 minutes in an electric muffle and again weigh. The difference between this weight and that previously obtained gives the weight of the silica (Note 4).

DETERMINATION OF TOTAL IRON AND ALUMINUM.

Iron and Alumina.

Fuse the residue from the silica determination using a little Na_2CO_3 (Note 5). Dissolve the cooled melt in HCl and add the solution to the filtrate from the second evaporation for silica. Add a few drops of bromine water or HNO_3 and boil the solution until all trace of bromine or chlorine is gone. Then add HCl, if not already present, sufficient to insure a total volume of 10 to 15 cc. of HCl (sp. gr. 1.20).[2] Add a few drops of methyl red solution and after diluting to 200 to 250 cc. heat the liquid to boiling. Neutralize by means of NH_4OH (dilute towards the end) until the color of the liquid changes to a distinct yellow. Boil for one or two minutes, allow to settle, filter and wash the precipitate at once two or three times with hot NH_4Cl (2-per-cent) solution and suck dry.[3]

Set the filtrate aside. Dissolve any precipitate from the paper in hot, dilute HCl, the solution passing into the beaker in which the precipitation was made and wash the paper thoroughly with hot water. Boil the solution to expel any trace of chlorine and again precipitate the hydroxides with NH_4OH as described above. Ignite the precipitate, moist (Note 1), in a weighed platinum crucible, cool and weigh as Al_2O_3 and Fe_2O_3 (Note 6).

DETERMINATION OF TOTAL IRON.

Total Iron.

Fuse the combined iron and aluminum oxides (Note 7) in a platinum crucible at a very low temperature with 3 to 4 g. of $K_2S_2O_7$ or better $Na_2S_2O_7$ (Note 8). Take up the melt with so much dilute H_2SO_4 that there shall be not less than 5 g. absolute acid and enough water to effect solution on heating. Evaporate the solution and eventually heat until acid fumes come off copiously. After cooling and redissolving in water, filter out the small amount of silica, wash, ignite, weigh and correct by HF and H_2SO_4 (Note 9). Add the weight so corrected to the weight of silica previously found and deduct from the gross weight of the oxides of iron and aluminum.

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[1] See *Bulletin 700*, U. S. Geological Survey, p. 103.

[2] See *Bulletin 700*, U. S. Geological Survey, p. 258.

[3] See *Bulletin 700*, U. S. Geological Survey, p. 107.

Reduce the filtrate by zinc (Note 10). Titrate with $KMnO_4$ using a N/20 solution.

DETERMINATION OF ALUMINUM.

Aluminum.

Subtract the calculated weight of Fe_2O_3 obtained by the method described above from the weight of $Fe_2O_3 + Al_2O_3$. Report the remainder as Al_2O_3. In case phosphorus is determined, calculate it to P_2O_5 and deduct also.

DETERMINATION OF TOTAL IRON.

ALTERNATIVE METHOD (Note 7).

Total Iron, Alternative.

Dissolve 2 to 5 g. (depending upon the amount of iron present) of the properly prepared sample in HCl and evaporate rapidly to dryness. Treat the residue with water and HCl, filter off the silica and wash several times with hot water. Precipitate the iron in a boiling solution with fixed alkali, allow to settle, filter and wash free of chlorides, using hot water. Dissolve in dilute H_2SO_4.

Ignite the insoluble matter from the evaporated hydrochloric acid solution in a platinum crucible. Treat with H_2SO_4 and HF and heat until fumes of H_2SO_4 appear. Bring the residue into solution with the addition of a few drops more of H_2SO_4 and combine the solution with that of the bulk of the iron. Reduce this solution by zinc and titrate the iron with $KMnO_4$ in the usual manner.

DETERMINATION OF CALCIUM.

(Note 11.)

(*a*) *Gravimetric Method.*

Calcium, Gravimetric.

Add a few drops of NH_4OH to the combined filtrate from the R_2O_3 precipitate, and bring the solution to boiling. To the boiling solution add 35 cc. of a saturated solution of $(NH_4)_2C_2O_4$, and continue the boiling until the precipitated CaC_2O_4 assumes a granular form; then allow it to stand 20 minutes, or until the precipitate has settled and the supernatent liquid is clear, filter and wash thoroughly with boiling water (Note 12). Place the wet filter and precipitate in a platinum crucible, and burn off the paper over the small flame of a Bunsen burner, or in a muffle. Ignite the residue, dissolve in hot dilute HCl, and make up the volume of the solution to 100 cc. with water. Add NH_4OH in slight excess and boil the liquid. If a small amount of $Al_2(OH)_6$ separates, filter it out, wash with NH_4Cl (2-per-cent solution), ignite, weigh and add this weight to that found in the first determination. Then reprecipitate the lime by $(NH_4)_2C_2O_4$, allow to stand until settled, filter, wash thoroughly with boiling water (Note 12) and weigh as calcium oxide after ignition to constant weight in a covered platinum crucible.

(*b*) *Volumetric Method.* (Note 13.)

Calcium, Volumetric.

Make the filtrate from the iron and alumina precipitate alkaline with NH_4OH, boil, and add 35 cc. of a boiling saturated solution of $(NH_4)_2C_2O_4$. Stir vigorously and allow to stand until the precipitate has settled, filter on an 11-cm. paper, and wash ten times with hot water (Note 14). Transfer the paper and precipitate to the beaker in which the precipitation was made, spreading the paper out against the upper portion of the beaker. Wash the precipitate from the paper with a jet of hot water, fold the paper and leave it adhering to the upper portion of the beaker. Add to the contents of the beaker 50 cc. of dilute H_2SO_4 (1:10), dilute to a volume of 250 cc. with hot water and heat to a temperature of 80 to 90° C. Titrate with the standard $KMnO_4$ solution[1] until the pink end point is obtained. Now drop the folded filter paper (which has been adhering to the side of the beaker) into the liquid; the pink color of the latter will be discharged. Finish the titration by adding $KMnO_4$, a drop at a time, until the pink end point is again obtained. A Gooch crucible may be used instead of filter paper. From the total quantity of standard $KMnO_4$ solution used, calculate the percentage of calcium oxide.

DETERMINATION OF STRONTIUM.

Strontium.

Transfer the weighed oxides obtained in the gravimetric determination of calcium to a small flask of 20-cc. capacity and dissolve in HNO_3. Evaporate to dryness and heat at 150 to 160° C. Treat the thoroughly dried nitrates with as little (rarely over 2 cc.) of a mixture of equal parts of absolute alcohol and ether as may be needed to dissolve the calcium salt, solution being hastened by occasional gentle agitation. After standing over night in the corked flask collect the insoluble matter on the smallest possible filter and wash with more of the above mixture of alcohol and ether. After drying, pass a few cubic centimeters of hot water through the filter, on which may remain a few tenths of a milligram of residue, which does not usually contain any lime or other alkaline earth and whose weight is therefore to be deducted from that of the lime, unless it can be shown that it is derived from the glass of the little flask in which the nitrates of calcium and strontium were evaporated. To the solution of strontium nitrate in a small beaker add a few drops of H_2SO_4 and then its volume of alcohol, whereby the strontium is precipitated as sulfate. After twelve hours, filter on a small filter paper and wash the residue with 50-per-cent alcohol. Ignite at a low temperature, moisten with dilute H_2SO_4, evaporate, again ignite and weigh as strontium sulfate. Test the sulfate spectroscopically as to freedom from calcium and barium.

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[1] See directions for preparing this solution.

Calculate the weight of strontium oxide and deduct from the weight of calcium oxide obtained as above.

DETERMINATION OF MAGNESIUM.

Magnesium.

Acidify the combined filtrates from the calcium precipitates with HCl and concentrate on the water bath to about 150 cc., and heat to boiling. To the boiling solution add 10 cc. of a saturated solution of $Na(NH_4)HPO_4$ and continue the boiling for several minutes. Then cool to room temperature, and add NH_4OH drop by drop with constant stirring until the crystallin ammonium-magnesium orthophosphate begins to form and then in moderate excess, the stirring being continued for several minutes. Allow the liquid to stand in a cool atmosphere for from 12 to 48 hours (Note 15) and filter.

Dissolve the precipitate in hot dilute HCl, make up the solution with water to about 100 cc., add 1 cc. of the saturated solution of $Na(NH_4)HPO_4$ and NH_4OH drop by drop with constant stirring until the precipitate is again formed as above described and the ammonia is present in moderate excess. Then allow it to stand in a cool atmosphere for from 12 to 48 hours (Note 15), filter on paper or a Gooch crucible, wash with dilute NH_4OH containing NH_4NO_3 (Note 16), ignite (Note 1), cool, and weigh as $Mg_2P_2O_7$ (Note 17).

DETERMINATION OF TOTAL VOLATILE MATTER.

(LOSS ON IGNITION.)

Volatile Matter.

Place 1 g. of the properly prepared sample (Note 18) in a weighed platinum crucible, cover with the lid and heat gently for 5 minutes (Note 1), gradually increasing the temperature to the maximum of the muffle, and maintain at this temperature until constant weight is obtained (usually about 15 minutes).

DETERMINATION OF MECHANICAL MOISTURE.

(LIMESTONE ONLY.) (Note 19.)

Mechanical Moisture.

Weigh 1 g. of the properly prepared sample in a tared, wide, low-form, flat-bottomed weighing bottle. Heat uncovered in a ventilated drying oven at 120° C. for two hours. Quickly stopper and cool in a desiccator. Lift the stopper momentarily just before weighing and weigh. The use of a similar weighing bottle as a counterpoise carried through all of the operations is a desirable procedure. The loss in weight represents "Mechanical Moisture" or "Hydroscopic Water" at 120° C.

DETERMINATION OF CARBON DIOXIDE.

Carbon Dioxide.

Carbon dioxide is to be determined upon the properly prepared sample according to the method given in U. S. Geological Survey Bulletin No. 700, p. 217. An illustration showing the arrangement of the component parts of the necessary apparatus is shown on p. 218 of that Bulletin.

With limestone, use a 0.5-g. sample; with burned lime, hydrated lime, etc., use a 5-g. sample.

Boil the weighed sample with dilute HCl in a small Erlenmeyer flask attached to an upwardly inclined condenser, whence, after passing through a drying system—calcium chloride, anhydrous copper sulfate to retain hydrogen sulfide from decomposable sulfides and any HCl that may pass over, then calcium chloride again—the carbon dioxide is caught by absorption tubes filled with soda-lime followed by calcium chloride. Of course, arrangement is made for a current of air free from CO_2 with which to sweep out the apparatus before and after the experiment, and for a slow current during its continuance.

The results are very accurate and the determination can be quickly carried out.

The manipulations are as follows: Pour hot water upon the powder in the flask fitted with a separatory funnel and delivery tube; attach this to the condenser, and force a current of air free from CO_2 through the whole system, except the weighed absorption tubes, until the original air has been displaced, the observation bulbs (containing H_2SO_4 to show the rate of gas flow) being attached directly to the drying system. Then close the stop-cock in the separatory funnel, half fill the latter with HCl (1:1), replace the rubber stopper of the funnel, insert the absorption tubes between the drying system and the observation bulbs, and allow the acid to flow into the flask, slowly if there is much carbon dioxide, rapidly if there is but little. When effervescence diminishes in the former case, at once in the latter, light the burner under the flask and start the flow of water through the condenser. Keep the flame low, so as to secure steady but quiet ebullition, and do not interrupt the air current although it should be reduced to a slow rate. With much carbon dioxide the rate of absorption is very readily noted by holding the hand to the soda-lime tubes, which become hot or warm when absorption is taking place. Sufficient time having elapsed (Note 20), extinguish the flame, and increase the air current. When cool, disconnect the soda-lime tubes from the apparatus and allow to stand in the balance case until two weights taken 30 minutes apart agree within 0.5 mg.

The soda lime for use in this determination must be porous, not hard and unabsorptive like that sometimes used for the combustion of nitrogenous organic substances.

DETERMINATION OF SULFURIC ANHYDRIDE.

Sulfuric Anhydride.

Place 2 g. of the properly prepared sample in a small, dry beaker and stir it up with 10 cc. of cold water until all lumps are broken up and the lighter particles are in suspension. Add 15 cc. of dilute HCl (1 : 1) and heat until solution is complete. Filter through a small paper and wash the residue thoroughly with hot water. Dilute the filtrate to 250 cc., heat to boiling, and add 10 cc. of a boiling 10-per-cent solution of barium chloride drop by drop with constant stirring. Stir well and allow to stand over night. Filter, wash with boiling water, ignite and weigh as $BaSO_4$.

DETERMINATION OF TOTAL SULFUR.

Total Sulfur.

Digest 2 g. of the properly prepared sample on the hot plate with 25 to 30 cc. of bromine water. Then add 15 cc. of dilute HCl (1:1) and boil until solution is complete and all bromine has been expelled. Then proceed as outlined above under "Determination of Sulfuric Anhydride."

DETERMINATION OF PHOSPHORUS.

Phosphorus.

Dissolve 10 g. of the sample in 80 cc. of dilute HNO_3 (1:1), filter, and wash the residue with hot water. Ignite, and fuse the residue with a little Na_2CO_3, cool the melt and add its nitric acid solution to the main filtrate. (Note 21.)

In case the rock is rather argillaceous, mix the powder with half its weight of Na_2CO_3 and blast strongly. Dissolve the cooled melt in HNO_3 and evaporate to dryness. Take up the dry residue with dilute HNO_3 (1 : 2), filter and wash the residue with hot water. Ignite the residue in platinum, and evaporate with HF and HNO_3. Finally, evaporate twice with HNO_3 alone to expel all fluorine, dissolve the residue in HNO_3 and add the solution to the main filtrate. (Note 21.)

Oxidize the nitric acid solution by boiling with 10 cc. of 1.5-per-cent $KMnO_4$ solution until manganese dioxide is precipitated. Dissolve the oxide by addition of H_2SO_3 or a sulfite free from phosphorus and boil to expel the oxides of nitrogen and sulfur. Neutralize the HNO_3 with NH_4OH and then add 1 cc. of HNO_3 (sp. gr. 1.42) for every 100 cc. of solution. Bring the solution to a temperature of 40° C., add ammonium molybdate solution[1] and shake for 10 minutes. Allow to stand at a temperature of not over 40° C. for 1 to 12 hours. Filter and wash 10 times with a 1-per-cent KNO_3 solution. Return the precipitate to the precipitating vessel, add a measured excess of N/10 NaOH and 25 cc. of water free from CO_2 and shake or stir until the precipitate is dissolved. Dilute to 100 to 200 cc. with water free from CO_2, add 3 drops of 0.2-per-cent phenolphthalein solution, and discharge the pink color with standard acid. Finish the titration by adding standard alkali until the reappearance of the pink color. The alkali solution should be free from carbonate and be standardized against the Bureau of Standards' standard benzoic acid.[2] The ratio of phosphorus to NaOH should be considered as 1 : 23 in calculating results. (Note 22.)

DETERMINATION OF MANGANESE.

Manganese.

Dissolve 10 g. of the sample in 100 cc. of dilute HNO_3 (1 : 1), filter and wash the residue with hot water. Ignite the residue in platinum, fuse with a little Na_2CO_3 and add the nitric acid solution of the melt to the main filtrate.

Dilute the solution to 150 cc. and add 0.5 g. of sodium bismuthate (Note 23). Heat for a few minutes, or until the pink color has disappeared and dioxide has precipitated. If manganese dioxide does not precipitate add more bismuthate. Clear the solution by adding a few drops of a saturated solution of sodium bisulfite or other suitable reducing agent free from chlorides, and boil to expel all oxides of nitrogen and sulphur. Cool to 15° C., add an excess of sodium bismuthate, agitate and let stand for a few minutes. Add 50 cc. of 3-per-cent HNO_3 and filter through asbestos. Wash with 3-per-cent HNO_3 until the washings run through colorless. Add a measured excess of a standard $FeSO_4$ solution and titrate back with a standard $KMnO_4$ solution of which the strength has been determined by means of the Bureau of Standards sodium oxalate. (Note 24.)

DETERMINATION OF FERROUS IRON SOLUBLE IN SULFURIC ACID.

Ferrous Iron.

In limestones, the presence of carbonaceous matter renders the exact or even approximate determination of ferrous iron often impossible. Nevertheless, even in its presence acceptable results are sometimes obtainable if there is not much of such matter and if it does not give with acid a colored solution. Occasionally limestones show films of manganese peroxide, which likewise interferes with the determination.

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[1] See Blair, "The Chemical Analysis of Iron," 8th Edition, p. 92.

[2] See *Journal*, Am. Chem. Soc., Vol. 34, p. 1027 (1912), and Vol. 35, p. 1309 (1913).

(a) In Absence of Carbonaceous Matter.

The powder, one to several grams, is introduced into a stout flask of about 200 to 250-cc. capacity and boiled with a little water till all air is expelled. While still boiling, dilute H_2SO_4 is added, a little at a time, till effervescence ceases, and then a further amount. Calcium sulfate precipitates, but the iron will remain in solution. The flame is then removed and a stopper tightly inserted, through which passes a small stop-cock funnel. When cool, or nearly so, cold water is poured into the funnel, the cock cautiously opened, and the water drawn into the flask, more water being poured into the funnel as fast as it empties, till the solution amounts to 100 to 150 cc. Such precaution to exclude air is hardly necessary in most cases, however, for in presence of H_2SO_4 the oxidation of ferrous iron is exceedingly slow. It is ordinarily quite sufficient to equalize the internal and external pressures by opening the cock, removing the stopper, and pouring in cold water. The flask is then brought under a burette containing dilute $KMnO_4$ solution and the iron titrated without delay. With a carbonate which is wholly decomposable without the aid of heat, solution may be accomplished in a flask filled with CO_2, using cold acid, whereby the danger of attack of silicates is lessened if these are present. If the preference is for the $K_2Cr_2O_7$ method of titration, HCl may be used instead of H_2SO_4, in absence of manganese peroxide. In this case there is, of course, no separation of an insoluble calcium salt, a fact which renders easier the subsequent determination of the iron in any insoluble residue the rock may yield. The ferrous iron thus found is mostly, if not altogether, that existing as carbonate.[1]

(b) In Presence of Carbonaceous Matter.

Decomposition is effected in a flask by dilute H_2SO_4 in an atmosphere of CO_2. With limestones and active agitation no heat need be used, but with dolomites it will be necessary. The solution is then quickly filtered through asbestos (in an atmosphere of CO_2 if much iron is present), the residue and filter washed a few times with water, and the filtrate titrated at once with permanganate. If it is colored by organic matter, the result may be in error. As above, HCl and titration by $K_2Cr_2O_7$ may be used in absence of manganese peroxide. In either case it is important to allow the acid to act no longer than is necessary and to filter quickly. A determination of the ferrous iron in the insoluble matter is usually not worth attempting, because of the admixed organic matter.

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[1] If a determination of ferrous iron in the insoluble residue is desired see U. S. Geological Survey *Bulletin 700*, p. 265.

PREPARATION OF STANDARD SOLUTION OF POTASSIUM PERMANGANATE.

Potassium Permanganate.

Prepare a solution of potassium permanganate containing 5.64 g. of the pure crystallized salt in each liter. Such a solution will be of such strength that 1 cc. will approximately equal 0.005 g. of CaO (Note 25).

The best and simplest way to prepare such a solution is to weigh out the required quantity of potassium permanganate and place in a bottle containing the proper volume of water a week or ten days before the solution is to be standardized. The bottle and its contents must be kept in a dark place and shaken occasionally for the first three or four days. When ready for standardization, siphon off the solution through a glass siphon into another bottle, leaving a depth of about one inch of solution undisturbed in the original bottle (Note 26). Thoroughly mix the solution in the second bottle by shaking and standardize as follows (Note 27):

Dissolve 0.5 g. of $Na_2C_2O_4$ (Note 28) in a 400-cc. beaker with 200 to 250 cc. of hot water (80 to 90° C.) and add 10 cc. of dilute H_2SO_4 (1 : 1) to the solution. Titrate at once with the permanganate solution being standardized, stirring vigorously and continuously. The permanganate solution must not be added more rapidly than 10 to 15 cc. per minute, and the last 0.5 to 1 cc. must be added dropwise, with particular care to allow each drop to be fully decolorized before the next is introduced. The excess of permanganate solution necessary to give the end point color is determined by running a blank determination in another beaker containing the same volume of acid and water present in the original beaker, and heated to the same temperature (Note 29). The value of the permanganate solution in grams of CaO per cubic centimeter of solution may be calculated from the following equations:

$$5Na_2C_2O_4 + 2KMnO_4 + 8H_2SO_4 = 5Na_2SO_4 + K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O.$$

$$5CaC_2O_4 + 2KMnO_4 + 8H_2SO_4 = 5CaSO_4 + K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O.$$

NOTES.

1. Ignitions in electric muffles are far superior to flame ignitions. If an electric muffle is not available, flame ignition and the blast lamp may be used.

2. If a platinum dish is not available, porcelain may be used. A glass container positively must *not* be used.

3. Instead of strong acid, that of half strength may be used and the heating begun at once.

4. For ordinary control work in the plant laboratory this correction may, perhaps, be neglected; the double evaporation must never be neglected.

5. Fusion with pyrosulfate is to be avoided on account of the subsequent introduction of sulfates into the solution.

6. This precipitate may also contain TiO_2, P_2O_5, and Mn_3O_4.

7. Where the iron is present in small quantities it is rather unsatisfactory to determine it in the ignited oxides from the 0.5-g. sample. Under these conditions the alternative method may be used.

8. The pyrosulfates are less troublesome and more effective than the bisulfates.

9. This correction for impurities should not be made when the hydrofluoric acid correction of the main silica determination has been omitted. After two evaporations, 1 to 2 mg. of silica are still to be found with the R_2O_3 precipitate.

10. Zinc will also reduce titanium. If this metal is to be determined and deducted from Al_2O_3, then H_2S must be used for reduction (boiling out the H_2S in a stream of CO_2 before titration). If titanium is not to be determined, the slight error introduced by its reduction with zinc is so small as to be negligible except in the most exact and detailed analyses.

11. The gravimetric method must be employed when a recovery of aluminum is desired, or when a determination of strontium is contemplated.

12. Care must be exercised in this washing, as 1000 cc. of boiling water will dissolve over 1 cg. of CaC_2O_4.

13. The volumetric method may be used for ordinary control work in the plant laboratory. It must be borne in mind that in this method all strontium oxide is reported as calcium oxide.

14. Use not more than 125 cc. for this washing.

15. The less the amount of magnesium present, the longer the precipitate must be allowed to settle.

16. Made by diluting NH_4OH with distilled water until the solution contains $2\frac{1}{2}$ per cent NH_3 by weight. Three or four drops of HNO_3 (sp. gr. 1.42) are then added.

17. When manganese is present in the limestone, it will be caught in large part with the magnesium precipitate. (See U. S. Geological Survey *Bulletin 700*, p. 134.) In case manganese was not eliminated before this precipitation, the weighed pyrophosphate must be dissolved in HNO_3, tested for manganese with bismuthate, the manganese determined and deducted as $Mn_2P_2O_7$.

18. This determination may be made if desired upon the 0.5-g. sample ignited for solution in HCl. See first page of these methods under " Treatment of Sample."

19. With burned lime and hydrated lime this determination may be omitted. Even when made in an atmosphere free from CO_2 the dried sample absorbs CO_2 sufficiently rapidly during weighing to make the result of questionable value.

20. Boiling for one minute is usually sufficient.

21. In limestones very low in phosphorus it may be deemed desirable to concentrate the phosphorus from a considerable weight of sample. In this case, proceed as directed by F. Hinden (*Zeitschr. Anal. Chemie*, Vol. 54, p. 214 (1915)), as follows: To the nitric acid solution of the large sample add a few drops of Fe_2Cl_6 solution and then NH_4OH until the liquid becomes slightly turbid. Then add 0.5 g. of pure precipitated $CaCO_3$ and boil for five minutes. Filter, dissolve the precipitate in dilute HNO_3 and proceed as above.

22. Titanium and vanadium, which interfere in this determination, should not be encountered in appreciable amounts in this class of material.

Instead of the specified alkalimetric titration method, the phosphorus in the phosphomolybdate may be determined as magnesium pyrophosphate (U. S. Geological Survey *Bulletin 700*, pp. 178–179), or by the reductor method (A. A. Blair, "Chemical Analysis of Iron," 8th Edition, pp. 91–92).

23. The persulfate method may be employed if desired.

24. The separation of manganese with the R_2O_3 precipitate by the use of bromine is not recommended on account of the incompleteness of the precipitation. Separation of manganese by means of ammonium sulfide after the ammonia precipitation is also undesirable on account of the introduction of the reagent and the slimy character of the precipitate.

See also Note 17 concerning the contamination of magnesium pyrophosphate by manganese pyrophosphate and the need of corrective measures when manganese is present in the material under analysis.

25. With high calcium limes, more than 50 cc. of this solution will probably be required to titrate the liberated oxalic acid. In such cases the use of a larger burette is to be preferred to increasing the strength of the permanganate solution.

26. The siphon should not extend nearer than 1 in. from the bottom of the original bottle.

27. This solution should be standardized at least once every week. It will be found more convenient to make a solution as above described and standardize it every week, than to attempt, by boiling and filtering, to make a solution which will not change.

28. Sodium oxalate for standardization of potassium permanganate solution should be purchased from the U. S. Bureau of Standards, Washington, D. C. This material is sold by the Bureau of Standards as Sample No. 40a.

29. When the end point is reached, the temperature of the solution should not be below 60° C.

TENTATIVE METHOD OF TEST

FOR

RESISTANCE OF FIRE-CLAY BRICK TO SPALLING ACTION.[1]

Serial Designation: C 38 – 21 T.

This method is issued under the fixed designation C 38; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Object. 1. The object of this test is to determine the resistance of high-duty fire-clay brick to spalling action, by subjecting them to repeated rapid temperature changes.

Preparation of Samples. 2. (*a*) The sample shall consist of at least five standard 9-in. brick or of five shapes, which may be cut to standard size with a grinding wheel.

(*b*) Test specimens of shapes such as boiler arch brick shall be cut to the standard 9-in. size. For this purpose a "cut-off" wheel is recommended.

(*c*) The test specimens shall be marked for identification and then subjected to a preliminary heat treatment by heating them uniformly in a suitable furnace to a temperature of 1400° C. (2552° F.), maintaining this temperature for five hours, and then allowing them to cool.

Procedure. 3. (*a*) The specimens shall be weighed and placed in a door of a furnace operated at 1350° C. (2462° F.), care being taken to prevent the direct heating of more than the $2\frac{1}{2}$ by $4\frac{1}{2}$-in. end. After one hour the specimen shall be withdrawn from the furnace and stood on end in a tank of flowing cold water from 10 to 21° C. (50 to 70° F.) so that the hot end of the brick will be immersed to a depth of 4 in. After three minutes the sample shall be withdrawn from the water, allowed to steam five minutes and then returned to the furnace. The door of the furnace shall be closed while the bricks are out to prevent the lowering of the temperature. The alternate heating and cooling shall be continued in hourly cycles until the end of the brick spalls off.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. W. H. Fulweiler, Secretary of Committee C-8 on Refractories, 319 Arch St., Philadelphia, Pa.

(*b*) When pieces begin to fall off, the sample is laid on a 4.5 by 9.0-in. asbestos board, divided into one hundred equal squares, and the approximate percentage of loss estimated after each removal from the water. After the completion of the test, the brick is again weighed and the percentage of loss determined.

(*c*) As an alternate for water dipping, air cooling may be used. This method should be used where the spalling is too rapid to get comparative results by the water dipping method. In this case the hot end of the brick shall be placed facing the air blast, 4 in. from the end of a 2-in. pipe from a $\frac{1}{4}$-h.p. blower, delivering between 28 and 30 cu. ft. of air per minute.

Reporting Results. 4. The report shall show the number of dips before loss started, the percentage of loss after each cooling, the total number of dips and the final percentage of loss by weight.

TENTATIVE METHODS

OF

MAKING COMPRESSION TESTS OF CONCRETE.[1]

Serial Designation: C 39 – 21 T.

These methods are issued under the fixed designation C 39; the final number indicates the year of original issue, or in the case or revision, the year of last revision.

ISSUED, 1921.

Scope.

1. These methods are intended to cover compression tests of concrete made in a laboratory where accurate control of quantities of materials and test conditions is possible. They are designed to apply primarily to hand-mixed concrete. These methods may be used with slight modification in making tests of concrete for wearing resistance, bond between concrete and steel, impermeability, etc. The investigation of machine-mixed concrete will require certain obvious changes in the method. For methods of conducting compression tests of concrete specimens made during the progress of construction work, see the Standard Methods of Making and Storing Specimens of Concrete in the Field (Serial Designation: C 31) of the American Society for Testing Materials.[2]

Preparation of Materials.

2. Materials shall be brought to room temperatures (65 to 75° F.). before beginning tests. Cement shall be stored in a dry place; preferably in covered metal cans. The cement shall be thoroughly mixed in advance, in order that the sample may be uniform throughout the tests. It shall be sifted through a No. 16 sieve and all lumps rejected. Aggregates shall be in a room-dry condition when used in concrete tests. In general, aggregates should be separated on the No. 4, $\frac{3}{8}$-in. and $1\frac{1}{2}$-in. sieves[3] and recombined to the average original sieve analysis for each batch. Fine aggregate should be separated into different sizes also, in cases where unusual gradings are being studied.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. J. C. Pearson, Secretary of Committee C-9 on Concrete and Concrete Aggregates, Bureau of Standards, Washington, D. C.

[2] 1921 Book of A.S.T.M. Standards.

[3] For specifications for sieves, see Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41 – 21T) of the American Society for Testing Materials, p. 586.

Sampling for Preliminary Tests.

3. Representative samples[1] of all concrete materials shall be secured for preliminary tests prior to the proportioning and mixing of the concrete. Cement test samples may be made up of a small quantity from each sack used in the concrete tests. Test samples of aggregates may be taken from larger lots by quartering.

Cement Tests.

4. Cement shall be subjected to test, using the methods described in the Standard Specifications and Tests for Portland Cement (Serial Designation: C 9) of the American Society for Testing Material.[2]

Fine Aggregate Tests.

5. Fine aggregates (passing through a No. 4 sieve) shall be subjected, when required, to the following tests:

(*a*) Sieve analysis test made in accordance with the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41 – 21 T) of the American Society for Testing Materials.[3]

(*b*) Test for organic impurities (natural sand only) made in accordance with the Tentative Method of Test for Organic Impurities in Sand for Concrete (Serial Designation: C 40 – 21 T) of the American Society for Testing Materials.[4]

(*c*) Test for quantity of silt, clay or dust made in accordance with the Standard Method of Test for Quantity of Clay and Silt in Sand for Highway Construction (Serial Designation: D 74) of the American Society for Testing Materials.[2]

(*d*) Test for unit weight made in accordance with the Standard Method of Test for Unit Aggregate for Concrete (Serial Designation: C 29 – 21) of the American Society for Testing Materials.[2]

(*e*) Strength test of 1 : 3 mortar by weight at 7 and 28 days in comparison with standard sand mortar.

Coarse Aggregate Tests.

6. Coarse aggregates (retained on a No. 4 sieve) shall be subjected when required to the following tests:

(*a*) Sieve analysis test as specified under Section 5 (*a*);

(*b*) Test for quantity of silt, clay or dust, as specified under Section 5 (*c*);

(*c*) Test for unit weight as specified under Section 5 (*d*).

Mixed Aggregate Tests.

7. The unit weight of mixed fine and coarse aggregates as used in concrete tests shall be determined in accordance with the method specified in Section 5 (*d*).

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[1] For methods of sampling large lots of deposits of aggregate, see the Tentative Methods of Sampling Stone, Slag, Gravel, Sand, etc. for Use as Highway Materials (Serial Designation: D 75 – 20 T) of the American Society for Testing Materials, *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[2] 1921 Book of A.S.T.M. Standards.

[3] See p. 586.

[4] See p. 585.

Proportioning. 8. The quantities of each size of aggregate to be used in each batch shall be determined on the basis of the sieve analysis and the unit weight of the mixed aggregate. The exact quantities of cement and of each size of aggregate for each batch shall be determined by weight. The quantity of water for each batch shall be accurately measured. The quantities of materials may be expressed as (*a*) 1 volume of cement to — volumes of total aggregrate mixed as used, or (*b*) 1 volume of cement, — volumes fine aggregate, and — volumes of coarse aggregate.

NOTE.—It is impracticable to give a general method for proportioning concrete for experimental purposes; the details will necessarily vary widely with the purpose for which the tests are made. The following procedure is suggested for specific cases:

(*a*) Vary the cement content by 10-per-cent intervals above and below assumed quantity.

(*b*) Vary the proportions of fine to coarse aggregate, measured separately, at intervals of 10 per cent.

(*c*) Vary the quantity of mixing water by intervals of 10 per cent.

Size of Test Pieces. 9. Compression tests of concrete shall be made on cylinders of a diameter equal to one-half the length. The standard shall be 6 by 12-in. cylinders where the coarse aggregate does not exceed 2 in. in size; for aggregates larger than 2 in., 8 by 16-in. cylinders shall be used; 2 by 4-in. cylinders may be used for mixtures without coarse aggregate.

Mixing Concrete. 10. (*a*) Concrete shall be mixed by hand in batches of such size as to leave a small quantity of concrete after molding a single test piece. The batch shall preferably be mixed in a shallow galvanized steel pan with a 10-in. bricklayer's trowel which has been blunted by cutting off about 2½ inches of the point, as follows:

(*b*) The cement and fine aggregate shall be mixed dry until the mixture is homogeneous in color;

(*c*) The coarse aggregate shall be added and mixed dry;

(*d*) Sufficient water shall be added to produce concrete of the required workability;

NOTE.—Concrete tests should be made on *plastic* mixtures. It is of the utmost importance that a uniform degree of workability be secured in tests involving comparisons of different materials and methods.

(*e*) The whole shall be mixed thoroughly until the entire mass is homogeneous in appearance.

Workability. 11. The workability or plasticity of each batch of concrete shall be measured immediately after mixing by one of the following methods:

(*a*) Slump test made in accordance with the methods described in the Tentative Specifications for Workability of Concrete for Concrete

Pavements (Serial Designation: D 62 – 20 T) of the American Society for Testing Material.[1]

(*b*) Flow test made by placing a metal form in the shape of a frustum of a cone $6\frac{3}{4}$ in. in top diameter, 10 in. in bottom diameter, 5 in. deep, on the table of the flow apparatus.[2] The fresh concrete shall be placed in the mold in two layers. Each layer shall be puddled and finished as described in Section 13. Immediately after molding, the form shall be removed by a steady upward pull; the specimen raised $\frac{1}{2}$ in. and dropped 15 times in about 6 seconds by means of a suitable cam and crank. The spread of the fresh concrete due to this treatment as compared with the original bottom diameter of the cone, expressed as a percentage, is the "flow."

Forms.

12. The forms shall preferably be of metal. Each form shall be provided with a machined metal base plate, and shall be oiled with a heavy mineral oil before using. Particular care shall be taken to obtain tight forms so that the mixing water will not escape during molding.

NOTE.—The best type of form consists of lengths of cold-drawn steel tubing, split along one element and closed by means of a circumferential band and bolt. Satisfactory forms can be made from lengths of steel water-pipe machined on the inside, from rolled metal plates, from galvanized steel, machined iron or steel castings. Paraffined cardboard molds will give good results under expert supervision.

Molding Test Pieces.

13. Concrete test pieces shall be molded by placing the fresh concrete in the form in layers 3 to 4 in. in thickness. Each layer shall be puddled with 25 strokes with a $\frac{5}{8}$ in. round steel bar of a length 9 in. greater than the length of the mold, pointed at the lower end. After the top layer has been puddled, the surplus concrete shall be cleaned off with a trowel, and the mold covered with a machined metal plate or a piece of plate glass at least $\frac{1}{4}$ in. thick, which will be used later in capping the test piece.

Capping Cylinders.

14. Two to four hours after molding, the test pieces shall be capped with a thin layer of stiff neat cement paste in order that the cylinders may present a smooth end for loading. The cap shall be formed by means of a machined metal plate or a piece of plate glass of suitable size, at least $\frac{1}{4}$ in. thick, worked down on the fresh cement paste until it rests on the top of the cylinder form. The cement for capping shall be mixed to a stiff paste before beginning to mix the concrete; in this way the tendency of the cap to shrink will be largely eliminated. The adhesion of the concrete to the metal base plate and the glass can be

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[2] For a description and illustration of one design for a flow-table, see *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part II, p. 242 (1920) and "Concrete," June, 1920, p. 274.

largely eliminated by oiling the cover plate and by inserting a sheet of paraffined tissue paper.

Curing Test Pieces. 15. Concrete test pieces shall be removed from the forms 20 to 48 hours after molding, marked, weighed and stored in damp sand, under damp cloths or in a moist chamber until the date of test. The temperature of the curing room should not fall outside the range of 60 to 75° F.

Age at Test. 16. Tests shall be made at the age of 7 and 28 days; ages of 3 months and 1 year are recommended, if longer-time tests are required.

Sequence of Tests. 17. Three to five test pieces should be made on different days in investigations in which accurate comparisons are desired.

Preparation of Tests. 18. Compression tests shall be made immediately upon removal of the concrete test pieces from the curing room; that is, the test pieces shall be loaded in a damp condition. The length and average diameter of the test piece shall be measured in inches and hundredths; two diameters shall be measured at right angles near the mid-length. The test piece shall be weighed immediately before testing.

Method of Testing. 19. In general, only the ultimate compressive strength of the cylinders need be observed. The metal bearing plates of the testing machine shall be placed in contact with the ends of the test piece; cushioning materials shall not be used. An adjustable bearing block shall be used to transmit the load to the test piece. The bearing block shall be placed on *top* of the test piece in vertical testing machines. The diameter of the bearing block shall be approximately the same as that of the test piece. The upper section of the bearing block shall be kept in motion as the head of the testing machine is brought to a bearing on the test piece.

Application of Load. 20. The load shall be applied uniformly and without shock. The moving head of the testing machine should travel at the rate of about 0.05 in. per minute when the machine is running idle.

Record of Tests. 21. The total load indicated by the testing machine at failure of the test piece shall be recorded and the unit compressive strength calculated in pounds per square inch, the area computed from the average diameter of the cylinder being used. The type of failure and appearance of the concrete shall be noted.

Weight of Concrete. 22. The weight of the concrete in pounds per cubic foot shall be determined from the weight of the specimens and their dimensions.

Density and Yield. 23. Density and yield of concrete when required shall be calculated from the unit volumes of the constituent materials and the volume of the concrete. Density is here understood to be the ratio of solids in the concrete to the total volume of the mass. Yield is the volume of concrete resulting from one volume of aggregate mixed as used.

Report of Tests.

24. The report of tests shall include the following:

(*a*) The kind and origin of concrete materials;

(*b*) Complete data on all tests of cement and aggregates;

(*c*) A description of methods of making and testing the concrete, where methods deviate from the proposed standards;

(*d*) The quantities of cement, aggregates and water in each batch;

(*e*) The method of measuring workability or plasticity with "slump" or "flow" of concrete;

(*f*) The quantity of water expressed as a ratio to volume of cement;

(*g*) The age at test;

(*h*) The size of test pieces;

(*i*) The date of molding and testing each cylinder;

(*j*) The compressive strength in pounds per square inch of each test piece and average of tests in a set;

(*k*) A description of failure and appearance of concrete on each test piece.

(*l*) The unit weight, density and yield of the concrete

TENTATIVE METHOD OF TEST
FOR
ORGANIC IMPURITIES IN SANDS FOR CONCRETE.[1]

Serial Designation: C 40 - 21 T.

This method is issued under the fixed designation C 40; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope 1. The test herein specified is an approximate test for the presence of injurious organic compounds in natural sands for cement mortar or concrete. The principal value of the test is in furnishing a warning that further tests of the sand are necessary before they be used in concrete. Sands which produce a color in the sodium hydroxide solution darker than the standard color should be subjected to strength tests in mortar or concrete before use.

Sample. 2. (*a*) A representative test sample of sand of about 1 lb. shall be obtained by quartering or by the use of a sampler.

Procedure. (*b*) A 12-oz. graduated glass prescription bottle shall be filled to the 4½-oz. mark with the sand to be tested.

(*c*) A 3-per-cent solution of sodium hydroxide (NaOH) in water shall be added until the volume of sand and liquid after shaking gives a total volume of 7 liquid ounces.

(*d*) The bottle shall be stoppered and shaken thoroughly and then allowed to stand for 24 hours.

(*e*) A standard color solution shall be prepared by adding 2.5 cc. of a 2-per-cent solution of tannic acid in 10-per-cent alcohol to 22.5 cc. of a 3-per-cent sodium hydroxide solution. This shall be placed in a 12-oz. prescription bottle, stoppered and allowed to stand for 24 hours, then 25 cc. of water added.

Color Value. (*f*) The color of the clear liquid above the sand shall be compared with the standard color solution prepared as in Paragraph (*e*) or with a glass of color similar to the standard solution.

3. Solutions darker in color than the standard color have a "color value" higher than 250 parts per million in terms of tannic acid.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. J. C. Pearson, Secretary of Committee C-9 on Concrete and Concrete Aggregates, Bureau of Standards, Washington, D. C.

TENTATIVE METHOD OF TEST
FOR
SIEVE ANALYSIS OF AGGREGATES FOR CONCRETE.[1]

Serial Designation: C 41 – 21 T.

This method is issued under the fixed designation C 41; the final number indicates the year of original issue, or in the case or revision, the year of last revision.

ISSUED, 1921.

Sampling. 1. A representative test sample of the aggregate shall be selected by quartering or by use of a sampler, which after drying will give not less than the following:

(*a*) Fine aggregate, 500 g.

(*b*) Coarse aggregate or a mixture of fine and coarse aggregates,

TABLE I.

Sieve Number[1] or Size in inches.	Sieve Opening.		Wire Diameter.		Tolerance, per cent.		
	in.	mm.	in.	mm.	Average Opening.	Wire Diameter.	Maximum Opening.
No. 100	0.0059	0.149	0.0040	0.102	6	20	40
No. 50	0.0117	0.297	0.0074	0.188	6	20	40
No. 30	0.0232	0.59	0.0130	0.33	4	10	25
No. 16	0.0469	1.19	0.0213	0.54	3	10	10
No. 8	0.0937	2.38	0.0331	0.84	3	10	10
No. 4	0.187	4.76	0.050	1.27	3	10	10
$\frac{3}{8}$-in.	0.375	9.5	0.092	2.33	3	10	10
$\frac{3}{4}$-in.	0.75	19.0	0.135	3.42	3	10	10
1-in.	1.00	25.4	0.162	4.12	3	10	10
$1\frac{1}{2}$-in	1.50	38.0	0.177	4.50	3	10	10
2-in.	2.00	50.8	0.192	4.88	3	10	10
3-in.	3.00	76.0	0.25	6.3	3	10	10

[1] Sieves No. 100 to No. 4 are based on "Table of Fundamental Data on Standard Specifications for Sieves" issued by the U. S. Bureau of Standards, 1920. The liberal tolerances will permit the use of certain sieves which do not exactly correspond to the numbers given in the table.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. J. C. Pearson, Secretary of Committee C-9 on Concrete and Concrete Aggregates, Bureau of Standards, Washington, D. C.

weight in grams, 3000 times size of largest sieve required, measured in inches.

Treatment of Sample.

2. The sample shall be dried at not over 110° C. (230° F.) to constant weight.

Sieves.

3. (*a*) The sieves shall be of square-mesh wire-cloth and shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sifting.

(*b*) The size of wire and sieve openings shall be as given in Table I.

Procedure.

4. (*a*) The sample shall be separated into a series of sizes by means of the sieves specified in Section 3. Sifting shall be continued until not more than 1 per cent by weight of the sample passes any sieve during 1 minute.

(*b*) Each size shall be weighed on a balance or scale which is sensitive to 1/1000 of the weight of the test sample.

(*c*) The percentage by weight of the total sample which is finer *than each* of the sieves shall be computed.

Report.

5. (*a*) The percentages in sieve analysis shall be reported to the nearest whole number.

(*b*) If more than 15 per cent of a fine aggregate is coarser than the No. 4 sieve, or more than 15 per cent of a coarse aggregate is finer than the No. 4 sieve, the sieve analysis of the portions finer and coarser than this sieve shall be reported separately.

TENTATIVE METHOD
OF
SECURING SPECIMENS OF HARDENED CONCRETE FROM THE STRUCTURE.[1]

Serial Designation: C 42 - 21 T.

This method is issued under the fixed designation C 42; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. The methods and precautions herein specified apply to securing test specimens from hardened concrete in the structure.

Precautions. 2. A specimen from hardened concrete to be tested for strength shall not be taken until the concrete has become hard enough so that the cutting of the specimen will not disturb the bond between the mortar content and the coarse aggregate of the specimen.

Apparatus. 3. The specimen from the structure can best be secured by use of a core drill. For specimens taken perpendicular to a horizontal surface, a drill using chilled shot may be used; but when taken perpendicular to a vertical surface, a diamond drill should be used.

Test Specimen. 4. (*a*) The core specimen taken shall be as nearly as possible a cylinder whose length is twice the diameter.

(*b*) In securing a specimen perpendicular to a horizontal surface care shall be taken to secure, if possible, a specimen whose beds shall be parallel to the horizontal bed of the concrete as originally placed.

(*c*) In securing a specimen perpendicular to a vertical surface, or to a surface with a batter, care shall be taken as to the point of securing the specimen. The lower portion of any one unit of depositing in mass concrete is more dense than is the upper portion of the unit, therefore a specimen shall be taken from near the middle of such unit of deposit.

Procedure. 4. A specimen to be taken from hardened concrete which has been removed from a structure shall be cut out by a drill or shall be cut into a symmetrical test-piece by tooling or by sawing. The method of sawing can seldom be used to advantage in the field. In selecting this test specimen care shall be used to see that the concrete selected has not been injured or shattered by the method of its removal from the structure.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. J. C. Pearson, Secretary of Committee C-9 on Concrete and Concrete Aggregates, Bureau of Standards, Washington, D. C.

5. The specimens secured shall have ends, or beds, as nearly as possible perpendicular to its axis, and, if the specimen has ends with uneven surfaces, these ends shall be made to parallel plane surfaces with a mortar richer than the mortar of the specimen or with a mixture of cement and calcined gypsum (plaster of Paris). **Ends.**

TENTATIVE METHODS OF TESTING GYPSUM AND GYPSUM PRODUCTS.[1]

Serial Designation: C 26 - 21 T.

These methods are issued under the fixed designation C 26; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1919; REVISED, 1920, 1921.

I. DETERMINATION OF FREE WATER IN GYPSUM.

Free Water. 1. (*a*) Not less than 1 lb. of the entire sample as received shall be weighed, spread out in a thin layer in suitable vessel, placed in a drying oven, and dried at 45° C. for 2 hours. It shall then be cooled in an atmosphere free from moisture, and weighed again. The loss of weight corresponds to the free water, and shall be calculated to percentage of sample as received.

(*b*) The dried sample shall be stored in an air-tight container until used.

II. DETERMINATION OF FINENESS.

Fineness. 2. Fineness shall be determined by screening a known weight of the dried sample through screens of the specified sizes and weighing the amount of material retained on each screen. The material shall be shaken through the screen with as little abrasion as possible.

The size of the sample to be used in this determination shall depend upon the size of grain of the sample. If the sample will all pass a No. 3 screen, 100 g. will be sufficient; if the largest particles are more than 1 in. in diameter, at least 1000 g. must be used. With these limitations the size of sample to be used is left to the discretion of the operator.

NOTE.—The sizes of the screens to be used are given in the Tentative Specifications for Gypsum (C 22 - 21 T), for Calcined Gypsum (C 23 - 21 T) of the American Society for Testing Materials[2] and in the Standard Specifications for Gypsum Plasters (C 28) of the American Society for Testing Materials,[3] covering the particular product examined.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

[2] See pp. 553 and 556.

[3] 1921 Book of A.S.T.M. Standards.

III. CHEMICAL ANALYSIS OF GYPSUM AND CALCINED GYPSUM.

Preparation of Sample.

3. Dry sample as in Section 1, and reduce about 10 g. until it all passes a 100-mesh sieve, using extreme care not to unduly expose the material to the action of moisture or to overheating. The sample shall be kept in an air-tight container until ready for use.

Combined Water.

4. Place 1 g. of the sample in a covered crucible and dry at 215 to 230° C. to constant weight. Calculate the loss of weight to percentage of sample as received and report as combined water.

Carbon Dioxide.

5. Place the residue obtained after drying, as described in Section **4**, in a suitable flask and dissolve it in dilute HCl (not stronger than 1 : 4) in such a way that the gas evolved can be collected in either soda lime or caustic potash and weighed. The solution should be boiled for one minute, and a current of CO_2-free air kept passing through the apparatus for $\frac{1}{2}$ hour. The increase of weight of the soda lime or caustic potash corresponds to the weight of carbon dioxide, which is to be calculated to percentage of sample as received.

Silica and Insoluble.

6. Place 0.5 g. of the sample prepared as described in Section 3 in a porcelain casserole. Add about 25 cc. of 1:5 HCl, and evaporate to apparent dryness on a hot plate. Cool and add enough concentrated HCl to wet thoroughly. Add about 10 cc. of water, boil, filter, and wash. Put the filtrate back in the same casserole. Evaporate it to dryness and heat to about 120° C. for one hour. Cool. Add enough concentrated HCl to wet thoroughly. Add about 25 cc. of water, boil, filter, and wash. Transfer the two papers containing the two precipitates to the same crucible, ignite, and weigh. Calculate this weight to percentage of sample as received.

Iron and Alumina.

7. To the filtrate obtained as described in Section 6, add a few drops of HNO_3 and boil to insure oxidation of the iron. Add 2 g. of NH_4Cl previously dissolved in water. Make alkaline with NH_4OH. Digest hot for a few minutes until the precipitate coagulates. Filter, wash, ignite the precipitate and weigh as $Fe_2O_3+Al_2O_3$. Calculate this weight to percentage of sample as received. This precipitate may be further treated to separate the two oxides, but this is generally unnecessary.

Lime.

8. (*a*) To the filtrate obtained as described in Section 7, add 5 g. of $(NH_4)_2C_2O_4$ dissolved in water. Digest hot for $\frac{1}{2}$ hour, making sure that the solution is always alkaline with NH_4OH. Filter, wash and ignite in a platinum crucible over a strong blast

to constant weight. Calculate this weight to percentage of sample as received.

(*b*) *Alternative Method.*—To the filtrate obtained as described in Section 7, add 5 g. of $(NH_4)_2C_2O_4$ dissolved in water. Digest hot for ½ hour, making sure that the solution is always alkaline with NH_4OH. Filter and wash. Transfer the precipitate to a beaker, and wash the filter paper with hot dilute H_2SO_4, catching the washings in the same beaker. Heat gently to complete solution, adding more H_2SO_4 if necessary. While still warm, titrate with a solution of $KMnO_4$ containing 5.6339 g. per liter, until the pink color is permanent. The number of cubic centimeters of $KMnO_4$ used gives directly the percentage of lime in the dried sample. Recalculate to percentage of sample as received.

Magnesia.

9. To the filtrate obtained as described in Section 8 (*a*) or (*b*), add enough water to give a total volume of about 600 cc. Cool. Add 10 cc. of NH_4OH and 5 g. $NaNH_4HPO_4$ dissolved in water. Stir until precipitate begins to form. Let stand over night. Filter, wash with a 2.5-per-cent by weight solution of NH_4NO_3. Ignite and weigh. Multiply this weight by 40/111 to find the weight of MgO. Then calculate to percentage of sample as received.

Sulfur Trioxide.

10. Dissolve 0.5 g. of the sample prepared as described in Section 3 in 50 cc. of 1 : 5 HCl. Boil. Add 100 cc. of boiling water, and continue boiling for 5 minutes. Filter immediately and wash thoroughly with hot water. Boil, and while boiling, add slowly 20 cc. of a boiling 10-per-cent solution of $BaCl_2$. Digest hot for one hour, or until precipitate settles. Filter and wash. Dry carefully. Ignite over Bunsen burner at lowest heat possible until filter paper is burned off. Ignite at bright red heat for 15 minutes, and weigh. Multiply this weight by 80/233 to determine the weight of SO_3. Then calculate to percentage of sample as received.

Sodium Chloride.

11. Dissolve in boiling water a 1-g. sample (prepared as described in Section 3), put on the filter and wash with 250 cc. of boiling water, then titrate the filtrate. Add two or three drops of potassium chromate solution and titrate with an N/20 solution of silver nitrate. Each cubic centimeter of silver nitrate solution = 0.002923 g. of sodium chloride. Calculate to percentage of sample tested.

Calculation of Results.

12. By the methods given above, the results are obtained and reported in the following form:

	Per cent.
Free water	
Combined water	
Silica and insoluble, SiO_2	
Iron and alumina, R_2O_3	
Lime CaO	
Magnesia, MgO	
Sulfur Trioxide, SO_3	
Carbon Dioxide, CO_2	
Sodium Chloride, NaCl	
	100.00 ±

NOTE.

Since it is frequenly advisable to recalculate these results, that they may be more enlightening, the following method is submitted for consideration:

(*a*) Multiply percentage of MgO by 84/40, to find percentage of $MgCO_3$.

(*b*) Multiply the percentage of MgO by 44/40 to find the percentage of CO_2 as $MgCO_3$.

(*c*) Deduct CO_2 as $MgCO_3$ from the CO_2 determined.

(*d*) Multiply the CO_2 remaining by 100/44 to find percentage of $CaCO_3$.

(*e*) Add together the percentage of SiO_2 R_2O_3, $MgCO_3$, and $CaCO_3$, and report in the aggregate.

(*f*) Multiply the percentage of $CaCO_3$ by 56/100 to find the percentage of CaO as $CaCO_3$.

(*g*) From the total percentage of CaO, deduct the percentage of CaO as $CaCO_3$. The remainder may be called "available CaO."

(*h*) The "available CaO" should bear to the SO_3 a ratio of 7 to 10. Determine which (if either) is in excess.

(*i*) If the CaO is in excess, multiply the SO_3 by 7/10, and subtract the result from the "available CaO." The remainder is reported as "excess CaO."

(*j*) If the SO_3 is in excess, multiply the "available CaO" by 10/7 and subtract the result from the SO_3. The remainder is reported as "excess SO_3."

(*k*) Add together the "available CaO," and the SO_3, and subtract the "excess CaO" or "excess SO_3." The remainder is $CaSO_4$.

(*l*) If the $CaSO_4$ is present as $CaSO_4 \cdot \frac{1}{2}H_2O$, the percentage of $CaSO_4$ should bear to the percentage of combined water a ratio of 136 to 9. Determine which (if either) is in excess.

(*m*) If the $CaSO_4$ is in excess some of it is present in the anhydrous form. Multiply the percentage of combined water by 136/9 to find the percentage of $CaSO_4$ as $CaSO_4 \cdot \frac{1}{2}H_2O$. The difference between the total $CaSO_4$ and the percentage of $CaSO_4$ as $CaSO_4 \cdot \frac{1}{2}H_2O$, is the $CaSO_4$ in the anhydrous form.

(*n*) If the water is in excess, some of the $CaSO_4$ is present as gypsum. Let x = percentage of $CaSO_4 \cdot \frac{1}{2}H_2O$, and y = percentage of $CaSO_4 \cdot 2H_2O$. Then $x+y$ = percentage of $CaSO_4$ (as found in *k*) + percentage of water.

$$\frac{9x}{136} + \frac{36y}{172} = \text{percentage of combined water.}$$

Solve these equations for x and y. Report x as percentage of "calcined gypsum," $CaSO_4 \cdot \frac{1}{2}H_2O$. Report y as percentage of gypsum, $CaSO_4 \cdot 2\ H_2O$.

Having made these calculations, the result may be reported as follows:

	Per cent.
Gypsum, $CaSO_4+2H_2O$	
Calcined gypsum, $CaSO_4+\frac{1}{2}H_2O$	
Anhydrite, $CaSO_4$	
Excess CaO or Excess SO_3	
Sodium chloride, NaCl	
Other ingredients	
	100.00±

The presence of the different forms of $CaSO_4$ may be corroborated by a microscopic examination.

IV. PRECAUTIONS FOR PHYSICAL TESTS.

Precautions for Physical Tests.

13. Gypsum products are peculiar in that their properties are very greatly affected by the small amounts of impurities which may be introduced by careless laboratory manipulation. In order to obtain concordant results, it is therefore absolutely essential to observe the following precautions:

(*a*) All apparatus shall be kept thoroughly clean. Especially shall all traces of set plaster be removed.

(*b*) Distilled water, free from chlorides and sulfates, shall be used throughout.

(*c*) Standard Ottawa sand shall be used throughout. This shall be prepared for use by washing it once with 1:4 HCl and four times with distilled water, and then drying it.

V. TESTING CONSISTENCY OF CALCINED GYPSUM.[1]

Normal Consistency.

14. In order that the results of testing samples of different plaster shall be directly comparable, it is necessary that all calcined gypsum be first brought to the same consistency, by the addition of the proper amount of water. An accurate method for determining this consistency is the most important step in the standardizing of physical methods for testing cementing materials.

Apparatus.

15. For a description of the apparatus to be used for measuring consistency, reference is made to the accompanying illustration (Fig. 1) of the Southard viscosimeter which has been used with satisfactory results.

The apparatus consists of a brass cylinder of 2-in. (5.08 cm.) bore with a circular disk flange flush with its upper end. The

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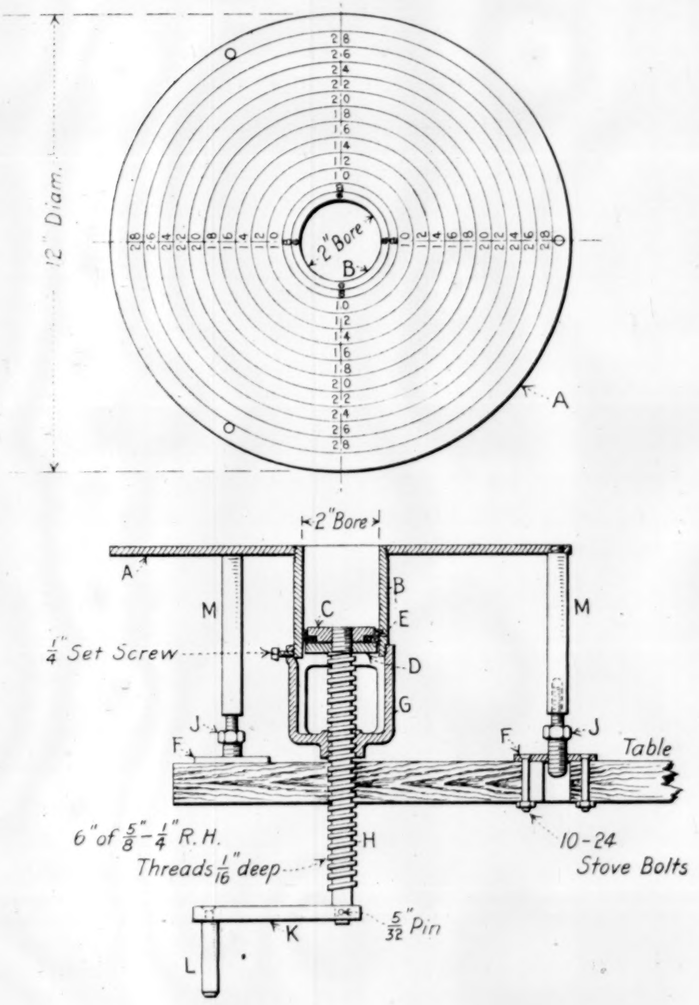
[1] Specifications for testing consistency of sanded mixtures to be supplied by the committee when the information is available.


12" Diam.
2" Bore
B
A
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
2" Bore
A
B
M
C
E
M
$\frac{1}{4}$" Set Screw
D
G
J
J
F
F
Table
6" of $\frac{5}{8}$"-$\frac{1}{4}$" R.H.
Threads $\frac{1}{16}$" deep
H
10-24
Stove Bolts
$\frac{5}{32}$" Pin
K
L

A; $\frac{3}{16}$" Hard Brass Plate Scale Disk.
B; 2" Ex. H. Seamless Brass Tube Cylinder.
C; Brass Piston Top.
D; " " Bottom.
E; Leather " Packing.
F; $\frac{3}{16}$" x 1" Flat Bar Steel Support Plate.
G; Brass Cage (Open on two Sides).
H; $\frac{5}{8}$" Hard Brass Piston Screw.
J; $\frac{1}{2}$" Hex. Brass Support Stud.
K; $\frac{3}{8}$" x $\frac{3}{4}$" C.R.S. Screw Lever.
L; $\frac{3}{8}$" Diam. C.R.S. Lever Handle.
M; $\frac{1}{2}$" Diam. C.R.S. Support Rod.

FIG. 1.—Southard Viscosimeter.

screw actuating the piston is $\frac{5}{8}$ in. (1.59 cm.) in outside diameter, $\frac{1}{4}$-in. (0.635 cm.) pitch, right-hand square threads $\frac{1}{16}$ in. (0.159 cm.) deep. The top of the brass disk flange is etched with concentric circles which vary in diameter from 6 cm. up to 28 cm. by increments of 2 cm.

When in position for use the brass flange is to be maintained in a true horizontal position.

Method. 16. To prepare this viscosimeter for use see that the piston, cylinder walls and top of plate are clean. Then by turning the crank, bring the top of the piston exactly flush with the top of the plate. Then by reverse cranking make ten complete turns, which will lower the piston to a point $2\frac{1}{2}$ in. (6.35 cm.) below the top of the plate. Make a mixture of at least 300 g. total of dry calcined gypsum and water. Shake the calcined gypsum into the water through a No. 8-mesh sieve allowing it to soak two minutes. Stir to an even fluidity for not to exceed 30 seconds. Pour this mixture immediately into the well in the center of the plate of the viscosimeter, filling the well just flush with the top of the plate. Then immediately turn the crank at the bottom of the viscosimeter ten turns at the rate of one turn per second. The upward motion of the piston will cause the mixture to overflow into a circular pat, it being understood that the top face of the circular disk of the instrument is to be adjusted and maintained in a true horizontal plane. Next take the average of the quadrant readings on the concentric lines on the top of the plate.

A mixture is of testing consistency, if with this operation, it gives a circular pat averaging 9.7 cm. in diameter, and shall be expressed as the number of cubic centimeters of water required to be added to 100 g. of the plaster.[1]

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[1] The following is recommended as a field method for the determination of testing consistency which will give fairly accurate results:

The apparatus shall consist of a piece of brass tubing 2 in. (5.08 cm.) in inside diameter and 4 in. (10.15 cm.) long, and a piece of plate glass about 8 in. (20.3 cm.) square. The brass tubing shall be cut off true and square at the ends, and to the exact length. Thoroughly wet the cylinder and glass plate by immersion in clean water Set the cylinder on end on top, and in the center of, the glass plate which is set and maintained in a true horizontal position.

Prepare a dry sample of calcined gypsum. Next make a mixture of calcined gypsum and water of sufficient quantity to slightly more than fill the cylinder. The mixture shall be made by adding the calcined gypsum to the water, allowing it to soak for two minutes. Now stir to an even fluidity for not to exceed 30 seconds, and at once pour this mixture into the cylinder so as to completely fill it level with the top.

Immediately raise the cylinder from the glass with a quick, straight and upward motion so as to withdraw it from the mixture within. This act will allow the mixture to leave the cylinder, assuming a cone-shaped circular pat upon the glass plate.

The testing consistency is a mixture which will give a circular pat averaging $4\frac{3}{4}$ in. (12 cm.) in diameter, and shall be expressed as the number of cubic centimeters of water required to be added to 100 g. of the plaster.

VI. WATER-CARRYING CAPACITY.

Water-Carrying Capacity.

17. The water carrying capacity is the amount of water, calculated as percentage by weight of the dry material, which is necessary to bring the mixture to testing consistency.

VII. DETERMINATION OF DRY BULK.

Dry Bulk.

18. Place a 10-mesh screen above a 20-mesh screen and holding the two screens together at a height of 12 in. (30 cm.) above a perpendicular-sided receptacle of known volume and of about 400 cc. content.

Place the material under test on top of the 10-mesh screen and pass it through the 10-mesh screen and 20-mesh screen, filling the receptacle under the 12-in. head, then strike off and obtain the net weight of the contents in grams. Obtain the average of three tests according to this method and express the average result in cubic centimeters per 100 g. Dry Bulk is the volume in cubic centimeters occupied by 100 g. of dry material.[1]

VIII. DETERMINATION OF WET BULK.

Wet Bulk.

19. Wet bulk is the volume in cubic centimeters occupied by a mixture of 100 g. of dry material mixed with water to testing consistency.

IX. DETERMINATION OF TIME OF SETTING.

Time of Setting.

20. Mix 200 g. of the sample with enough water to make a paste of testing consistency. The directions for mixing are given under "Testing Consistency."

NOTE.—If the sample is a sanded mixture use 300 g. and mix to testing consistency for sanded mixture.

Fill a rubber mold with the paste, and test for time of set with a Vicat needle. The specifications for the mold and needle are given in the Standard Specifications for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.[2]

When conducting the test, the needle is allowed to sink into the paste at frequent intervals. After each penetration, the needle must be wiped clean, and the paste moved slightly so that the needle will not strike the same hole twice.

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[1] Dry Bulk is expressed as the volume in cubic centimeters occupied by 100 g. of dry material instead of "grams per 100 cc." since Bulk is understood to mean Volume per Unit Weight rather than Weight per Unit Volume.

[2] 1921 Book of A.S.T.M. Standards.

The frequency of the penetrations will depend upon the character of the material. If the sample is not retarded, it should be tested every two minutes until nearly set, and then every minute. If the sample is retarded, the intervals at first may be as long as one hour, but in any case they must be so selected that the time of set is ascertained to the nearest minute.

Set is considered complete when the needle no longer penetrates to the bottom of the paste. The minutes elapsed, from the time when the sample was first added to the water, to the time when set is complete, is recorded as the time of set of the sample.

> *Caution:* For test to determine the time of set, it is absolutely essential that all dishes and utensils be clean. Especially must they be free from all traces of set gypsum. Use distilled water.

NOTE.—The relative merits of the "Penetration" and "Temperature Rise methods for determining initial and final set, are being investigated by the U. S. Bureau of Standards.

X. DETERMINATION OF TENSILE STRENGTH.

Tensile Strength. 21. Mix 500 g. of the sample to testing consistency. Cast into a three-gang briquette mold, of the shape and size used for testing Portland cement, see the Standard Specifications for Portland Cement (Serial Designation: C 9) of the American Society for Testing Materials.[1] Do not cast each briquette successively, but move the containing vessel back and forth over the molds while pouring continuously. Work the briquette slightly with the point of the trowel to remove air bubbles, and level off the briquettes. When sufficiently hard, remove and store in the room at a temperature of not less than 15°.6 C. (60° F.) nor more than 37°.8 C. (100° F.) for at least seven days. Weigh once a day. When the weight has become constant to within 0.1 per cent, proceed to test the specimens in a standard machine used for the determination of tensile strength.

NOTE.—When the material to be tested is a sanded mixture, use not less than 750 g. of the sample and mix to testing consistency for sanded mixture.

The average tensile strength shall be reported as the tensile strength of the material, except that if one or two briquettes vary more than 15 per cent from the average, the tensile strength shall be reported as the average of the remaining specimens. The tensile strength of all briquettes shall be reported.

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[1] 1921 Book of A.S.T.M. Standards.

XI. DETERMINATION OF COMPRESSIVE STRENGTH.

Compressive Strength.

22. Mix 2000 g. of the sample to testing consistency. Cast into five 2 by 4-in. split cylinders set plumb upon a metal or glass plate. Do not cast each cylinder successively, but move the containing vessel back and forth over the cylinders while pouring continuously. Work the cylinders slightly with the point of the trowel to remove air bubbles, and level off the top of the cylinders. When sufficiently hard, remove and store in the room at a temperature of not less than 15°.6 C. (60° F.) nor more than 37°.8 C. (100° F.) for at least seven days, and by weighing once a day, when the weight has become constant to within 0.1 per cent, proceed to test the specimens in a standard machine used for the determination of compressive strength.

NOTE.—When the material to be tested is a sanded mixture use not less than 3000 g. of the sample and mix to testing consistency for sanded mixture.

The average compressive strength shall be reported as the compressive strength of the material, except that if one or two of the cylinder specimens vary more than 15 per cent from the average, the compressive strength shall be reported as the average of the remaining specimens. The compressive strength of all the cylinders shall be reported.

XII. DETERMINATION OF SAND-CARRYING CAPACITY OF CALCINED GYPSUM.

Sand-Carrying Capacity.

23. It is the sense of the committee that sand-carrying capacity cannot be defined by tensile strength. A method of measuring sand-carrying capacity should be based upon the working quality of the plaster when mixed with varying amounts of sand. The methods adopted should be independent of the nature of surface to which the sanded mixture is applied.

This problem may be solved by measuring the relative plasticities of sanded mixtures, and the committee will have it under consideration during the coming year.

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO THE GYPSUM INDUSTRY.[1]

Serial Designation: C 11 - 21 T.

These definitions are issued under the fixed designation C 11; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1916; Revised, 1921.

Accelerator.—The term accelerator shall apply to any material or substance which, when used in stucco, plaster, concrete, etc., will hasten set beyond the limit of allowable error.

Aggregate.—The term aggregate shall refer to the inert material used as filler in stucco, plaster, mortar, concrete mixtures, etc., without regard to its function as a binding material.

Binder.—The term binder shall refer to any material which will increase the cohesiveness of plaster and stucco while in its plastic state.

Cement.—The term cement applies to any material, or a mixture of materials which, when in a plastic state, possesses adhesive and cohesive properties, and hardens in place. The word "cement" is used without regard to the composition of the material, and does not define its use or location as do the words "stucco," "plaster" and "mortar."

Consistency.—The term consistency is used to denote the degree of wetness of a plastic mixture.

Keene's Cement.—The term Keene's Cement refers to a completely dehydrated gypsum, chemically treated.

Mortar.—The term mortar applies to any material used in a plastic state that can be trowelled, and becomes hard in place, uniting such materials as brick, stone, tile, gypsum tile or blocks, terra cotta, etc., in building walls, partitions, columns, foundations, piers, floors, roof arches, etc. The word "mortar" is used without regard to the composition of the material, defining its use as a bonding material as contrasted with the words "stucco" and "plaster."

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[1] Criticisms of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr V. G. Marani, Secretary of Committee C-11 on Gypsum, 111 W. Washington St., Chicago, Ill.

Plaster.—The term plaster applies to any material used in a plastic state to form a hard covering for the interior surfaces, walls and ceilings, etc., of any building or structure. The word "plaster" is used without regard to the composition of the material, defining only its use and location of use as contrasted with the words "stucco" and "mortar."

Plasticity.—The term plasticity is used to denote the yielding property of a wet mixture to change of form.

Retarder.—The term retarder applies to any material or substance which, when used in stucco, plaster, mortar, concrete, etc., will retard set beyond the limit of allowable error.

Stucco.—The term stucco refers to any material used in a plastic state to form a hard covering for the exterior walls or other exterior surfaces of any building or structure. The word "stucco" is used without regard to the composition of the material, defining only its use and location of use, as contrasted with the words "plaster" and "mortar."

Wood Fiber.—The term wood fiber applies to a material produced by grinding or shredding wood.

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO HOLLOW TILE.[1]

Serial Designation: C 43 – 21 T.

These definitions are issued under the fixed designation C 43; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

I. TILE.

1. *Clay Hollow Tile.*—Hollow burned clay building units with parallel cells.

2. *Terra Cotta.*—A term applying to ornamental building units of burned clay but frequently used, erroneously, to designate hollow tile.

3. *Hollow Building Tile.*—Hollow tile for use in load-bearing structural members such as floors and walls.

4. *Load-Bearing Tile.*—Tile for use in members designed to carry load.

(*a*) *Floor Tile.*—Hollow building tile for use as a structural material in floors in conjunction with steel or reinforced concrete.

(*b*) *Foundation Tile.*—Hollow tile used below the first floor or grade line for carrying the superstructure; also for building piers or pilasters below grade.

(*c*) *Side Construction Tile.*—Tile designed to receive its principal stress at right angles to the direction of its cells.

(*d*) *End Construction Tile.*—Tile designed to receive its principal stress parallel to the direction of its cells.

(*e*) *Back-up Tile.*—Hollow building tile of suitable dimensions for use as backing in walls faced with brick or stone.

(*f*) *Book Tile.*—Hollow tile resembling a book in shape designed to fill space between supporting members of roof or similar structures and having tongue and groove edges.

(*g*) *Vitrified Tile.*—Tile burned to a temperature to produce vitrification but not necessarily glazed.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr. C. C. Crockatt, Secretary of Committee C-10 on Hollow Building Tile, The Hollow Building Tile Association, Conway Building, Chicago, Ill.

(*h*) *Salt-Glazed Tile.*—Tile with a vitreous glaze on its surface produced by burning salt in the kiln at the temperature used in finishing the burning.

5. *Hollow Tile Fireproofing.*—Hollow tile for use in non-bearing partitions or for furring or for the protection of structural members against fire.

(*a*) *Partition Tile.*—Hollow tile for use in building interior partitions subdividing areas into rooms or for enclosing stairways or shafts and carrying no superimposed load.

(*b*) *Furring Tile.*—Split tile of suitable design for lining the inside of masonry walls.

(*c*) *Porous Tile.*—Tile in which the natural porosity of the clay has been increased by the admixture of other ingredients.

II. RAW MATERIALS.

6. *Shale.*[1]—A soft, fragile rock, made from clay, having an uneven, slaty structure.

7. *Fire Clay.*[1]—A term commonly applied to buff burning clays underlying coal veins and to other buff or brown burning clays which mature at moderate or high temperatures.

8. *Surface Clay.*[1]—A term commonly applied to soft, plastic clays which mature at comparatively low temperatures.

III. DESIGNATION OF DIMENSIONS.

9. *Thickness.*—That dimension of a tile measured at right angles to the face of the wall or floor as it lies in the wall or floor.

10. *Width.*—That dimension of a tile measured at right angles to the direction of its thickness and cells.

11. *Length.*—That dimension of a tile measured between its cut ends.

NOTE.—In practice the first dimension given represents thickness, the second width, the third length.

IV. PARTS, OPENINGS AND SURFACE FEATURES.

12. *Shells.*—The outer walls of the tile.

13. *Webs.*—Partitions parallel to the cells.

14. *Cells.*—The openings in a hollow tile running parallel with its shells and webs.

15. *Scoring.*—The grooves formed in the exterior faces of the shells of the tile to increase the bond of mortar, or plaster.

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[1] Definitions of the terms shale, fire clay and surface clay and of clays in general as applied to refractories, are now under consideration by Committee E-8 on Nomenclature and Definitions, in cooperation with the several standing committees interested.—ED.

TENTATIVE SPECIFICATIONS

FOR

TURPENTINE.[1]

Serial Designation: D 13 – 21 T.

These specifications are issued under the fixed designation D 13; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1920; REVISED, 1921.

Material Covered. 1. These specifications apply both to the turpentine that is distilled from pine oleoresins, commonly known as "gum spirits" or "spirits of turpentine," and to turpentine commonly known as "wood turpentine," which is obtained from resinous wood, whether by steam or by destructive distillation. When ordering under these specifications, the purchaser shall specify whether (*a*) gum spirits or (*b*) wood turpentine is desired. When wood turpentine is specified, it may be stated whether steam or destructively distilled wood turpentine shall be furnished.

I. PROPERTIES AND TESTS

2. Turpentine shall be pure and conform to the following requirements:

Appearance. 3. The turpentine shall be clear and free from suspended matter and water.

Color. 4. The color shall be "Standard" or better.

Odor. 5. The odor shall be characteristic of the variety of turpentine specified and, if desired, shall conform to the odor of the sample agreed upon.

Other Properties. 6. Other properties shall be as follows:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

These Tentative Specifications are in effect a revision of the Standard Specifications for Turpentine. The Standard Specifications, which were last published under the Serial Designation: D 13 – 15, have accordingly been withdrawn.

	Maximum.	Minimum.
Specific gravity, 15.5/15°.5 C.	0.875	0.862
Refractive index at 20° C.—		
Gum spirits	1.478	1.468
Wood turpentine	1.478	1.465
Residue after polymerization with 38 N H_2SO_4:		
Gum spirits—		
Volume, per cent	2.0	.....
Refractive index at 20° C.	.....	1.500
Wood turpentine—		
Volume, per cent	2.5	.....
Refractive index at 20° C.	.....	1.48
Initial boiling point at 760 mm. pressure	160° C.	150° C.
Distilling below 170° C. at 760 mm. pressure, per cent	.....	90

II. DETECTION AND REMOVAL OF SEPARATED WATER.

7. Draw a portion by means of a glass or metal container with a removable stopper or top, or with a "thief," from the lowest part of the container, or by opening the bottom valve of the perfectly level tank car. If water is found to be present, draw it all out, record the quantity, and deduct it from the total volume of liquid delivered.

III. SAMPLING.

8. The method of sampling given under (*a*) shall be used whenever feasible. When method (*a*) is not applicable, method (*b*), (*c*), or (*d*) shall be used according to the special conditions that obtain.

(*a*) *While Loading Tank Car or While Filling Containers for Shipment.*—Samples shall be drawn by the purchaser's inspector at the discharge pipe where it enters the receiving vessel or vessels. The composite sample shall be not less than 5 gal. and shall consist of small portions of not more than 1 qt. each taken at regular intervals during the entire period of loading or filling.

The composite sample thus obtained shall be thoroughly mixed and from it three samples of not less than 1 qt. each shall be placed in clean, dry, glass bottles or tin cans, which shall be nearly filled with the sample and securely stoppered with new, clean corks or well-fitting covers or caps. These shall be sealed and distinctly labeled by the inspector; one shall be delivered to the purchaser, one to the seller, and the third held for check in case of dispute.

(*b*) *From Loaded Tank Car or Other Large Vessel.*—The composite sample taken shall be not less than 5 gal. and shall consist of numerous small samples of not more than 1 qt. each taken from the top, bottom, and intermediate points by means of a metal or glass container with removable stopper or top. This device, attached to a suitable pole, is lowered to the various desired depths, when the stopper or top is removed and the container allowed to fill. The sample thus obtained is handled as in method (*a*).

(*c*) *Barrels and Drums.*—Barrels and drums shall be sampled after gaging contents. Five per cent of the packages in any shipment or delivery shall be represented in the sample. Thoroughly mix the contents of each barrel to be sampled by stirring with a clean rod and withdraw a portion from about the center by means of a "thief" or other sampling device. The composite sample thus obtained shall be not less than 3 quarts, shall consist of equal portions of not less than ½ pt. from each package sampled, and shall be handled as in method (*a*). Should the inspector suspect adulteration, he shall draw the samples from the suspected packages.

(*d*) *Small Containers, Cans, etc., of 10 Gal. or Less.*—These shall be sampled, while filling, by method (*a*) whenever possible; but in case this is impossible the composite sample taken shall be not less than 3 qt. This shall be drawn from at least five packages (from all when fewer), and in no case from less than 2 per cent of the packages. The composite sample thus taken shall be thoroughly mixed and subdivided as in method (*a*).

IV. LABORATORY EXAMINATION.

9. Samples will, in general, be tested by the following methods; but the purchaser reserves the right to apply any additional tests or use any available information to ascertain whether the material meets the specifications.

Appearance. 10. Examine to determine compliance with the specifications.

Color. 11. Fill a 200-mm. perfectly flat-bottomed colorimeter tube, graduated in millimeters, to a depth of from 40 to 50 mm. with the turpentine to be examined. Place the tube in a colorimeter and place on or under it a No. 2 yellow Lovibond glass. Over or under a second graduated tube in the colorimeter, place a No. 1 yellow Lovibond glass and run in the same turpentine until the color matches as nearly as possible the color in the first tube. Read the difference in depth of the turpentine in the two tubes. If this difference is 50 mm. or more, the turpentine is "Standard" or better.

Odor.

12. Determine odor by comparison with several samples of known purity, which have been kept in the dark in completely filled, well-stoppered bottles and are free from separated water.

Specific Gravity.

13. Determine specific gravity at 15.5/15°.5 C., in a pyknometer accurately standardized and having a capacity of at least 25 cc.; or by any other equally accurate method.

Refractive Index.

14. Determine refractive index at 20° C. with an accurate instrument. When the refractive index is determined at any other temperature, the readings obtained shall be corrected to 20° C. by adding to or by subtracting from the actual reading 0.00045 for each degree Centigrade that the temperature at which the determination was made is, respectively, above or below 20° C.

Distillation.

15. *Apparatus.*[1]—(*a*) *Condenser.*—The type of apparatus is shown in Fig. 1, or may be the apparatus proposed in the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products (Serial Designation: D 86 - 21 T.) of the American Society for Testing Materials,[2] substituting for the thermometer there described an immersed thermometer, such as is described below.

(*b*) *Flask.*—Comparable results can be obtained only by using flasks of the same dimensions. The distilling flask used shall be the standard Engler flask, as used for petroleum distillation, having the following dimensions: Diameter of bulb, 6.5 cm.; cylindrical neck, 15 cm. long, 1.6 cm. internal diameter; side or vapor tube, 10 cm. long, 0.6 cm. external diameter, attached to neck at an angle of 75 deg., so that when the flask contains its charge of 100 cc. of oil the surface of the liquid shall be 9 cm. below the bottom of the junction of the side tube and neck.

(*c*) *Support for Flask.*—Support the flask on a plate of asbestos 20 cm. in diameter, having an opening 4 cm. in diameter in its center, and heat with an open flame. Surround the flask and burner with a shield to prevent fluctuation in the temperature of the neck of the flask. Or, support the flask in a metal cup, 15 to 20 cm. in diameter, containing high-boiling mineral oil or glycerin and fitted with a concave cover having in the center a circular opening 5½ to 6 cm. in diameter. In all cases take the necessary precautions to prevent fluctuation in temperature in the neck of the flask.

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[1] The flask, condenser, shield, ring support and hard asbestos board, gas burner or electric heater, described in the Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar Petroleum Products (Serial Designation: D 86 - 21 T) of the American Society for Testing Materials (p. 631) which are essentially the same as the equipment herewith described, may be employed in the distillation test wherever it is available.

[2] See p. 631.

(*d*) *Thermometer.*—The thermometer used for turpentine distillation shall conform to the following specifications:

It shall be graduated from 145° to at least 200° C. in 0°.2 intervals. Length, bottom of thermometer to 175° mark, not more than 8 nor less than 6.5 cm. Length, top of bulb to 145° mark, not less than 1.5 cm. Length, 145 to 175° mark, not more than 6 cm. Thermometers graduated above 200° C. may be used, provided they also comply with the foregoing requirements.

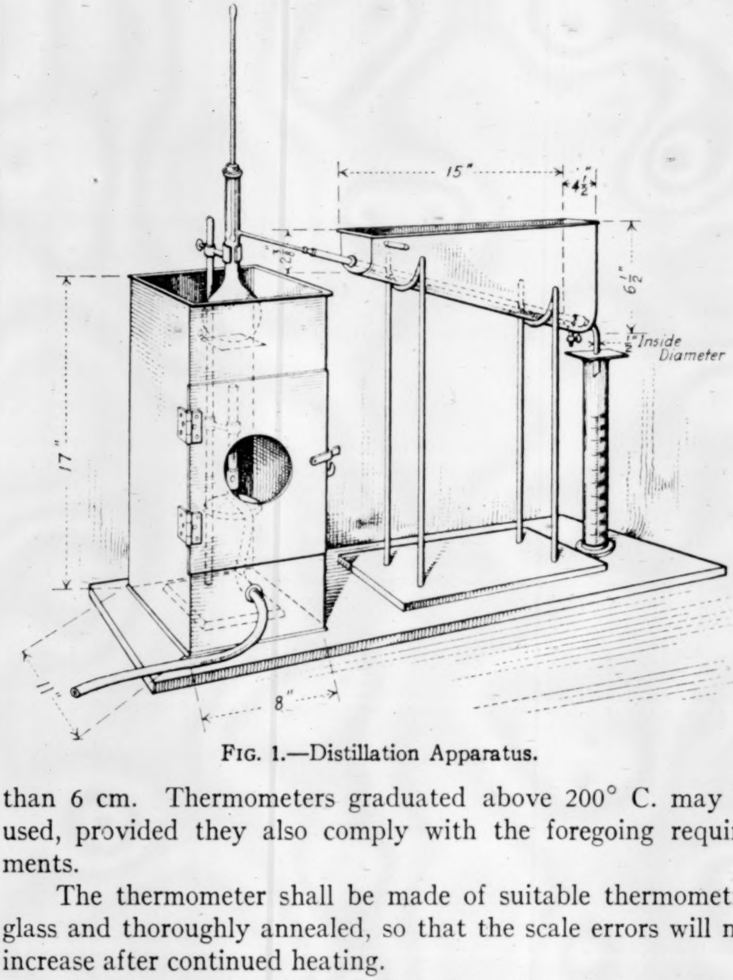

FIG. 1.—Distillation Apparatus.

The thermometer shall be made of suitable thermometric glass and thoroughly annealed, so that the scale errors will not increase after continued heating.

The thermometer shall be filled above the mercury with an inert gas, with sufficient pressure above the mercury column to prevent breaking of the column. It shall have a reservoir at the top, so that the pressure will not become excessive at the highest temperature.

Every fifth graduation shall be longer than the intermediate ones, and the marks shall be numbered at each interval of 5°. The graduation marks shall be clear-cut and fine and the numbering clear-cut and distinct.

The error at any point on the scale shall not exceed ±0°.5 C. when tested for total immersion of the mercury column.

(*e*) *Receiving Cylinder.*—Collect the distillate in an accurately graduated 50 or 100-cc. cylinder. The so-called normal or precision cylinder of 50 cc. capacity, having an internal diameter of 1.5 cm. and graduated in 0.2 cc., is preferred. If a cylinder with larger inside diameter is used, a pasteboard cover should be placed over the top and surround the condenser tube.

16. *Operation.*—Place 100 cc. of the turpentine and several small pieces of pumice (or glass) in the distilling flask, fit the thermometer so that the top of the mercury bulb is level with the bottom of the side tube, and the 175° C. mark is below the cork. Place the flask in position on the asbestos board or oil bath and connect with the condenser. Apply the heat cautiously at first, and, when distillation begins, regulate the heat so that the turpentine distills at the rate of not less than 4 nor more than 5 cc. per minute (appromixately two drops per second). The initial boiling point is the thermometer reading at the instant when the first drop falls from the end of the condenser. Discontinue distillation when the temperature reaches 170° C., or an equivalent thereof, depending on the atmospheric pressure, as described in Section 17; let the condenser drain and read the percentage distilled.

The percentage distilled below successive selected temperatures and the temperature at which each successive 10 cc. distills may also be determined, if desired, making the necessary correction of the temperature for variations in atmospheric pressure.

17. *Correction for Variation in Atmospheric Pressure.*—Since distillation results are comparable only when obtained under exactly the same pressure conditions, turpentine shall be distilled at that pressure which, at room temperature, is equivalent to a pressure of 760 mm. of mercury at 0° C. Whenever the atmospheric pressure after correcting to 0° C. is other than 760 mm., a correction shall be made. Since alteration of the pressure in the distilling system requires rather complicated apparatus, it is simpler to alter the temperature observation points to correspond to the prevailing pressure.

To determine what the atmospheric pressure at the prevailing room temperature, or at the temperature of the barometer, would be at 0° C., read the barometer and the thermometer alongside when about to begin distillation. Refer to Table I. Under the column nearest the observed pressure reading, and on the line nearest the observed temperature of the barometer will be found the correction which must be subtracted from the observed pressure reading to obtain the equivalent, or true, reading at 0° C.

The distilling temperature of turpentine is affected plus (+) or minus (−) 0°.057 C. for each millimeter variation of the barometer above or below the normal 760 mm. at 0° C.[1] If the barometer reading, after correcting to 0° C., is below 760 mm., the turpentine will distill at a slightly lower temperature than under normal pressure. Therefore, the temperature recorded at the beginning of distillation (and any others observed during the course of the distillation) must be corrected to get its equivalent at normal pressure. The final temperature observation point (170° C., Section 16) must be altered accordingly to get its equivalent at the pressure (corrected to 0° C.) at which distillation is made.

TABLE I.—CORRECTION TO BAROMETER READINGS.[1]

(From Circular F, Instrument Division, Weather Bureau, U. S. Department of Agriculture.)

Temperature deg. Cent.	Observed Reading of Barometer, mm.														
	640	650	660	670	680	690	700	710	720	730	740	750	760	770	780
15.0	1.56	1.59	1.61	1.64	1.66	1.69	1.71	1.74	1.76	1.78	1.81	1.83	1.86	1.88	1.91
16.0	1.67	1.69	1.72	1.75	1.77	1.80	1.83	1.85	1.88	1.90	1.93	1.96	1.98	2.01	2.03
17.0	1.77	1.80	1.83	1.86	1.88	1.91	1.94	1.97	1.99	2.02	2.05	2.08	2.10	2.13	2.16
18.0	1.88	1.91	1.93	1.96	1.99	2.02	2.05	2.08	2.11	2.14	2.17	2.20	2.23	2.26	2.29
19.0	1.98	2.01	2.04	2.07	2.10	2.13	2.17	2.20	2.23	2.26	2.29	2.32	2.35	2.38	2.41
20.0	2.08	2.12	2.15	2.18	2.21	2.25	2.28	2.31	2.34	2.38	2.41	2.44	2.47	2.51	2.54
21.0	2.19	2.22	2.26	2.29	2.32	2.36	2.39	2.43	2.46	2.50	2.53	2.56	2.60	2.63	2.67
22.0	2.29	2.33	2.36	2.40	2.43	2.47	2.51	2.54	2.58	2.61	2.65	2.69	2.72	2.76	2.79
23.0	2.40	2.43	2.47	2.51	2.54	2.58	2.62	2.66	2.69	2.73	2.77	2.81	2.84	2.88	2.92
24.0	2.50	2.54	2.58	2.62	2.66	2.69	2.73	2.77	2.81	2.85	2.89	2.93	2.97	3.01	3.05
25.0	2.60	2.64	2.68	2.72	2.77	2.81	2.85	2.89	2.93	2.97	3.01	3.05	3.09	3.13	3.17
26.0	2.71	2.75	2.79	2.83	2.88	2.92	2.96	3.00	3.04	3.09	3.13	3.17	3.21	3.26	3.30
27.0	2.81	2.85	2.90	2.94	2.99	3.03	3.07	3.12	3.16	3.20	3.25	3.29	3.34	3.38	3.42
28.0	2.91	2.96	3.00	3.05	3.10	3.14	3.19	3.23	3.28	3.32	3.37	3.41	3.46	3.51	3.55
29.0	3.02	3.06	3.11	3.16	3.21	3.25	3.30	3.35	3.39	3.44	3.49	3.54	3.58	3.63	3.68
30.0	3.12	3.17	3.22	3.27	3.32	3.36	3.41	3.46	3.51	3.56	3.61	3.66	3.71	3.75	3.80
31.0	3.22	3.27	3.32	3.37	3.43	3.48	3.53	3.58	3.63	3.68	3.73	3.78	3.83	3.88	3.93
32.0	3.33	3.38	3.43	3.48	3.54	3.59	3.64	3.69	3.74	3.79	3.85	3.90	3.95	4.00	4.05
33.0	3.43	3.48	3.54	3.59	3.64	3.70	3.75	3.81	3.86	3.91	3.97	4.02	4.07	4.13	4.18

[1] These corrections apply to a mercurial barometer with brass scale. They can, however, be used for a mercurial barometer with glass scale, since the errors introduced thereby are negligible as applied to the work contemplated in this circular. For exact correction to be applied to such a barometer see Smithsonian Physical Tables, p. 119 (1914). An aneroid barometer should not be relied on.

For barometer readings below 640 mm. the correction can be interpolated, since the difference, at any particular temperature for each 10 mm. variation in barometer reading is practically constant.

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[1] Landolt-Börnstein Physikalisch-Chemische Tabellen, Ed. 4, Table 127, p. 435

For example, if the barometer reading, after correcting to 0° C., is 750 mm., the correction of the observed initial distilling temperature will be $0.057 \times 10 = 0^\circ.6$ C. approximately. If the reading of the thermometer when the turpentine begins to distill is 155°.6 C., the corrected initial distilling temperature will be $155^\circ.6 + 0^\circ.6 = 156^\circ.2$ C. Furthermore, the temperature observation point at end of distillation (170° C. at 760 mm.) must be altered to the same extent. Since the turpentine is distilling 0°.6 C. below what it would at normal pressure, distillation must be discontinued at 0°.6 C. below the specified limit of 170° C. to determine the percentage distilling below 170° C.

If the barometer reading corrected to 0° C. is above 760 mm., subtract the temperature correction from the observed thermometer reading to determine the initial distilling point, and continue distillation to 170° C. plus the correction to determine the percentage distilling below 170° C.

Polymerization.

18. (*a*) Place 20 cc. of 38 *N* (equivalent to 100.92 per cent H_2SO_4) sulfuric acid in a graduated, narrow-necked Babcock flask, stopper, and place in ice water to cool. Add slowly, from a pipette, 5 cc. of the turpentine to be examined. Gradually mix the contents, keeping warm, but being very careful that the temperature does not rise above 60° C. When the mixture no longer warms up on shaking, agitate thoroughly and place the flask in a water bath and heat at 60 to 65° C. for not less than 10 minutes, keeping the contents of the flask thoroughly mixed by vigorous shaking for one-half minute each time, six times during the period. Do not stopper the flask after the turpentine has been added, as it may explode. Cool to room temperature, fill the flask with concentrated sulfuric acid until the unpolymerized oil rises into the graduated neck and centrifuge from four to five minutes at not less than 1200 r. p. m., or for 15 minutes at 900 r. p. m., or allow to stand, lightly stoppered, for 12 hours. Calculate the percentage, note the consistency and color, and determine the refractive index (at 20° C.) of the unpolymerized residue. The consistency should be viscous and the color straw or darker.

(*b*) *Reagent for Testing.*—In a weighed glass-stoppered bottle (the regular $2\frac{1}{2}$-liter acid bottle is of a convenient size) mix ordinary concentrated sulfuric acid (sp. gr. 1.84) with fuming sulfuric acid. If the fuming acid used contains 50 per cent excess SO_3, the ratio of one part, by weight, of the former to three-fourths of a part, by weight, of the latter will give a mixture slightly stronger than the required strength. To determine the exact strength of this mixture in terms of H_2SO_4, weigh exactly, in a weighing pipette of about 10 cc. capacity, approximately 20 g. of the acid. Allow it to flow down the sides of the neck into a 1000-cc. volumetric flask containing about 200 cc. of distilled water. When the pipette has drained, wash all traces of the acid remaining in the pipette into the flask, taking precautions to prevent loss of SO_3, and make up to the mark. Titrate 20-cc. portions, drawn from a burette, against half normal alkali. Calculate the concentration in terms of the percentage of H_2SO_4 in the sample taken.

In the same way determine the percentage of H_2SO_4 in the stock of ordinary concentrated acid (sp. gr. 1.84). From these data calculate the quantity of the latter which must be added to the quantity of mixed acid in the weighed bottle to bring it to a concentration, in terms of H_2SO_4, of 100.92 per cent.

After adjusting the concentration by the addition of the ordinary sulfuric acid, thoroughly shake the bottle of mixed acid and again determine its concentration. The allowable variation is ±0.05 per cent H_2SO_4. Finally as a check run a polymerization test on gum turpentine known to be pure. The residue should fall below 2 per cent.

Special precautions must be taken to prevent dilution of this acid by the absorption of atmospheric moisture. The arrangement shown in Fig. 2 is most suitable for storing and delivering measured quantities of this reagent.

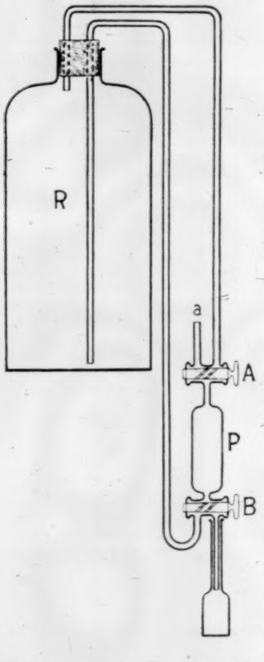

FIG. 2.—Acid Bottle and Pipette.

With the three-way stopcocks *A* and *B* in the position shown, acid is siphoned into the pipette *P*, the displaced air passing into *R*. To empty the pipette, *A* and *B* are turned to the position shown by the broken lines, air passing in at *a*. The acid adhering to the walls of the pipette dries this air so that when it passes into *R* on again filling the pipette there is no accumulation of moisture in the acid remaining in the reservoir. If such arrangement is not to be had, the acid should be kept in well-fitting glass-stoppered bottles of not more than one-half liter capacity.

TENTATIVE SPECIFICATIONS
FOR
PURITY OF RAW LINSEED OIL FROM SOUTH AMERICAN SEED.[1]

Serial Designation: D 77 – 21 T.

These specifications are issued under the fixed designation D 77; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

I. PROPERTIES AND TESTS.

1. Properly clarified raw linseed oil from South American seed shall conform to the following requirements:

	MAXIMUM.	MINIMUM.
Specific Gravity at 15°.5/15°.5 C	0.9360	0.9310
Acid Number	6.00	......
Saponification Number	195	189
Unsaponifiable Matter, per cent	1.50	......
Refractive Index at 25° C	1.4805	1.4780
Iodine Number (Hanus)	......	170

II. METHODS OF TESTING.

2. The oil shall be tested in accordance with the methods recommended in Section 2 of the Standard Specifications for Purity of Raw Linseed Oil from North American Seed (Serial Designation: D 1) of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
PURITY OF BOILED LINSEED OIL FROM SOUTH AMERICAN SEED.[1]

Serial Designation: D 78 – 21 T.

These specifications are issued under the fixed designation D 78; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

I. PROPERTIES AND TESTS.

1. Boiled linseed oil from South American seed shall conform to the following requirements:

	Maximum	Minimum
Specific Gravity at 15°.5/15°.5 C	0.945	0.936
Acid Number	8.00	......
Saponification Number	195	189
Unsaponifiable Matter, per cent	1.50	......
Refractive Index at 25° C	1.4840	1.4780
Iodine Number (Hanus)	......	168
Ash, per cent	0.7	0.2
Manganese, per cent	......	0.03
Calcium, per cent	0.3	......
Lead, per cent	......	0.1

II. METHODS OF TESTING.

2. The oil shall be tested in accordance with the methods recommended in Section 2 of the Standard Specifications for Purity of Boiled Linseed Oil from North American Seed (Serial Designation: D 11)[2] of the American Society for Testing Materials.[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS

FOR

ZINC OXIDE.[1]

Serial Designation: D 79 – 21 T.

These specifications are issued under the fixed designation D 79; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Scope.

1. These specifications cover the pigments commonly known as "Zinc White", or Zinc Oxide, purchased either in the form of dry pigment or ground in oil to form a paste.

I. MANUFACTURE.

Process.

2. (*a*) *Dry Pigment.*—The pigment may be made by the American process direct from the ore, or by the French process from spelter. The order or contract shall state which is desired.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The pigment shall conform to the following requirements:

	American Process.		French Process.	
	Maximum.	Minimum.	Maximum.	Minimum.
Coarse particles retained on a Standard No. 200 screen,[2] per cent[3]	0.0	..	0.0	..
Zinc oxide, per cent	...	98	...	99
Total sulfur, per cent	0.2	..	0.1	..
Total impurities, including moisture, per cent	2.0	..	1.0	..

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[3] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C–9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

The color and color strength, when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

(*b*) *Paste.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. The paste shall conform to the following requirements as to composition:

	MAXIMUM.	MINIMUM.
Pigment, per cent	86	82
Linseed oil, per cent	18	14
Coarse particles and skins (total residue retained on a Standard No. 200 screen[1] based on pigment), per cent[2]	0.5	..
Moisture and other volatile matter, per cent	0.5	..

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test. 5. In case of disagreement, the methods of analysis given in U. S. Bureau of Standards Circular No. 87 (1920) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

TENTATIVE SPECIFICATIONS

FOR

LEADED ZINC OXIDE.[1]

Serial Designation: D 80 - 21 T.

These specifications are issued under the fixed designation D 80; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Scope. 1. These specifications cover the pigment commonly known as Leaded Zinc Oxide, and consisting of zinc oxide with varying amounts of lead compounds, purchased either as dry pigment or ground in oil to form a paste.

I. MANUFACTURE.

Process. 2. (*a*) *Dry Pigment.*—The pigment shall be made by the collection of the fumes or dust arising from furnace operations on materials containing zinc.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment in pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties. 3. (*a*) *Dry Pigment.*—The pigment shall conform to the following requirements:

	High-leaded.		Low-leaded.	
	Maximum.	Minimum.	Maximum.	Minimum.
Coarse particles retained on a Standard No. 200 screen,[2] per cent[3]	0.0	..	0.0	..
Zinc oxide (ZnO), per cent	...	60	...	93
Water-soluble salts, per cent	1.0	...	1.0	..
Total impurities, including moisture, per cent	1.5	..	1.5	..

The remainder shall be normal or basic lead sulfate.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[3] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

The color and color strength, when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

(*b*) *Paste.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. The paste shall conform to the following requirements as to composition:

	MAXIMUM.	MINIMUM.
Pigment, per cent	88.0	....
Linseed oil, per cent	....	12.0
Moisture and other volatile matter, per cent	0.5	....
Coarse particles and skins (total residue retained on a Standard No. 200 screen[1] based on pigment), per cent[2]	0.5	....

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test. 5. In case of disagreement, the methods of analysis given in U. S. Bureau of Standards Circular No. 88 (1920) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

TENTATIVE SPECIFICATIONS
FOR
BASIC CARBONATE WHITE LEAD.[1]

Serial Designation: D 81 – 21 T.

These specifications are issued under the fixed designation D 81; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Scope.

1. These specifications cover what is commonly known as Basic Carbonate White Lead as used as a pigment and in putty, purchased either as dry pigment or ground in oil to form a paste.

I. MANUFACTURE.

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be the product made from metallic lead and shall have a composition corresponding approximately to the formula $2PbCO_3.Pb(OH)_2$. It shall be thoroughly washed after corroding, shall be free from impurities and adulterants, and shall meet the requirements given in Section 3.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The pigment shall conform to the following requirements:

	MAXIMUM.	MINIMUM.
Coarse particles retained on a Standard No. 200 screen,[2] per cent[3]	None	....
Lead carbonate, per cent	75.0	65.0
Total impurities, including moisture, per cent	2.0	....

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[3] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

The color and color strength, when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

(*b*) *Paste.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. The paste shall consist of:

	MAXIMUM.	MINIMUM.
Pigment (as specified above), per cent	92	90
Linseed oil, per cent	10	8
Moisture and other volatile matter, per cent	0.7	..
Coarse particles and skins (total residue retained on a Standard No. 200 screen[1] based on pigment), per cent[2]	0.5	..

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test. 5. In case of disagreement, the methods of analysis given in U. S. Bureau of Standards Circular No. 84 (1919) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance

TENTATIVE SPECIFICATIONS
FOR
BASIC SULFATE WHITE LEAD.[1]

Serial Designation: D 82 – 21 T.

These specifications are issued under the fixed designation D 82; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Scope.

1. These specifications cover the pigment commonly known as "basic sulfate" white lead. The pigment may be purchased in the dry form or ground in oil to form a paste.

I. MANUFACTURE.

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be the sublimed product prepared from lead sulfide ores, and shall be free from impurities and adulteration.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The dry pigment shall meet the following requirements:

	MAXIMUM.	MINIMUM.
Coarse particles retained on a Standard No. 200 screen,[2] per cent[3]	0.0	....
Lead oxide, per cent	18.0	11.0
Zinc oxide, per cent	9.0	....
Total impurities, including moisture, per cent	1.0	..

The remainder shall be lead sulfate.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[3] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

The color and color strength, when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

(*b*) *The Paste.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. It shall mix readily in all proportions, without curdling, with linseed oil, turpentine, or volatile mineral spirits or any combination of these substances.

The paste shall meet the following requirements:

	MAXIMUM.	MINIMUM.
Pigment, per cent	91.0	89.0
Linseed oil, per cent	11.0	9.0
Moisture and other volatile matter, per cent	0.7	...
Coarse particles and skins (total residue retained on a Standard No. 200 screen,[1] based on pigment), per cent[2]	0.5	...

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test. 5. In case of disagreement, the methods of analysis given in U. S. Bureau of Standards Circular No. 85 (1920) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

TENTATIVE SPECIFICATIONS

FOR

RED LEAD.[1]

Serial Designation: D 83 - 21 T.

These specifications are issued under the fixed designation D 83; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Scope.

1. These specifications cover red lead to be used as a pigment, purchased in the form of dry pigment or ground in oil to form a paste.

I. MANUFACTURE.

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be made by roasting litharge or lead, or compounds of lead which yield litharge by heating.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment in pure raw or refined linseed oil.

NOTE.—Avoid storing red lead paste in places of high temperature, as heat accelerates the tendency of this material to cake or harden.

Purchasers are cautioned not to buy red lead in paste form unless it is to be used within three months after shipment by the contractor.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The pigment shall consist entirely of oxides of lead, free from all adulterants and shall meet the following requirements:

	85-PER-CENT GRADE.	95-PER-CENT GRADE.
True red lead, Pb_3O_4, minimum, per cent....	85.0	95.0
Total impurities, including moisture, soluble matter, water, and matter insoluble in a mixture of nitric acid and hydrogen peroxide, maximum, per cent................	1.0	1.0

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

	85-PER-CENT GRADE.	95-PER-CENT GRADE.
The remainder shall be lead monoxide (PbO)		
Coarse particles retained on a Standard No. 200 screen,[1] maximum, per cent[2]	0.3	0.3

When mixed with raw linseed oil, turpentine and liquid drier, in the proportions:

Dry red lead	20 lb.
Raw linseed oil	5 pt.
Turpentine	2 gills
Liquid drier	2 "

the resulting paint, when brushed on a smooth vertical iron surface, shall dry hard and elastic without running, streaking or sagging.

(*b*) *Paste.*—The paste as shipped by the contractor, and for three months thereafter, shall not be caked in the container and shall readily break up in oil to form a smooth paint of brushing consistency. The paste shall have the following composition:

	MAXIMUM.	MINIMUM.
Pigment, per cent	94.0	92.0
Linseed oil, per cent	8.0	6.0
Moisture and other volatile matter, per cent	0.5	...
Coarse particles and skins (total residue retained on a Standard No. 200 screen,[1] based on pigment), per cent[2]	0.5	...

When mixed with raw linseed oil, turpentine and liquid drier in the following proportions:

Red lead paste	20 lb.
Raw linseed oil	4½ pt.
Turpentine	2 gills
Liquid drier	2 "

the resulting paint, when brushed on a smooth vertical iron surface, shall dry hard and elastic without running, streaking or sagging.

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test. 5. In case of disagreement, the methods of analysis given in the U. S. Bureau of Standards Circular No. 90 (1920) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

TENTATIVE SPECIFICATIONS

FOR

IRON OXIDE AND IRON HYDROXIDE.[1]

Serial Designation: D 84 – 21 T.

These specifications are issued under the fixed designation D 84; the final number indicates the year o original issue, or in the case of revision, the year of last revision.

Scope.

1. These specifications cover iron oxide and iron hydroxide pigments of red and brown colors.

I. MANUFACTURE.

Process.

2. (*a*) *Dry Pigment.*—The pigment shall be very finely ground iron oxide or iron hydroxide or a mixture thereof. Siliceous minerals may be present and, if necessary, sufficient carbon pigment may be added to produce the desired color.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The pigment shall meet the following requirements:

	MAXIMUM.	MINIMUM.
Ferric oxide, per cent	...	30.0
Material other than ferric oxide, insoluble siliceous matter and loss on ignition, per cent	10.0	...
Coarse particles retained on a Standard No. 200 screen,[2] per cent[3]	0.0	...

Organic coloring matters shall be absent.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[3] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

The color and color strength when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

(*b*) *Paste.*—The paste as received and three months thereafter shall not be caked in the container and shall break up readily in linseed oil to form a smooth paint of brushing consistency. It shall mix readily with linseed oil, turpentine or volatile mineral spirits, or any combination of these, without curdling.

The paste shall meet the following requirements:

	MAXIMUM.	MINIMUM.
Pigment, per cent	72.0	68.0
Linseed oil, per cent	32.0	28.0
Moisture and other volatile matter, per cent	0.7	....
Coarse particles and skins (total residue retained on a Standard No. 200 screen,[1] based on pigment), per cent[2]	0.5	....

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test 5. In case of disagreement, the methods of analysis given in U. S. Bureau of Standards Circular No. 93 (1920) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C–9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance

TENTATIVE SPECIFICATIONS

FOR

OCHER.[1]

Serial Designation: D 85 – 21 T.

These specifications are issued under the fixed designation D 85; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Scope.

1. These specifications cover ferrous earthy pigments, included under the general term "Ocher" and purchased either as dry pigment or ground in oil to form a paste.

I. MANUFACTURE.

General Composition.

2. (*a*) *Dry Pigment.*—The pigment shall be a hydrated oxide of iron, permeating a siliceous base, and shall be free from added impurities and added coloring matter.

(*b*) *Paste.*—The paste shall be made by thoroughly grinding the specified pigment with pure raw or refined linseed oil.

II. PROPERTIES AND TESTS.

Composition and Properties.

3. (*a*) *Dry Pigment.*—The pigment shall conform to the following requirements:

	Maximum.	Minimum.
Coarse particles retained on a Standard No. 200 screen, per cent	0.0	..
Iron oxide, per cent	...	17
Lime (CaO), per cent	5	..
Lead chromate, per cent	None	..
Organic colors, per cent	None	..

The color and color strength when specified, shall be equal to that of a sample mutually agreed on by buyer and seller.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

(*b*) *Paste.*—The paste as received shall not be caked in the container and shall break up readily in oil to form a smooth paint of brushing consistency. The paste shall meet the following requirements for composition:

	MAXIMUM.	MINIMUM.
Pigment, per cent	71	69
Linseed oil, per cent	31	29
Moisture and volatile matter, per cent	0.5	..
Coarse particles and skins (total residue retained on a Standard No. 200 screen[1] based on pigment), per cent[2]	0.5	..

Number of Tests. 4. One sample shall be taken at random from each lot of 1000 packages or less. If the packages are of such size that 1000 packages amount to more than a carload, one sample shall be taken at random from each carload.

Methods of Test. 5. In case of disagreement, the methods of analysis given in U. S. Bureau of Standards Circular No. 91 (1920) shall be used.

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[1] Finer screens are desirable but are not at present readily obtainable. Purchasers may agree with the sellers on additional requirements and tests for fineness.

[2] Specifications for a Standard No. 200 screen will be found in the Standard Specifications and Tests for Portland Cement (Serial Designation: C-9) of the American Society for Testing Materials (1921 Book of A.S.T.M. Standards). A diameter of 3 in. instead of 8 in. is recommended in order that the screen may be weighed directly on an analytical balance.

TENTATIVE DEFINITIONS OF TERMS RELATING TO PAINT SPECIFICATIONS.[1]

Serial Designation: D 16 - 21 T.

These definitions are issued under the fixed designation D 16 ; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Size.—In the painting art a size is a liquid material, the principal vehicle of which is water, and one which contains as a necessary ingredient a fairly large proportion of water soluble binder with or without pigment. A size is used to prepare a surface for further treatment and is not regarded as a finishing material.

Varnish.—A liquid coating material, containing no pigment, which flows out to a smooth coat when applied, and dries to a smooth glossy, relatively hard, permanent solid when exposed to the air in thin films.

Some varnish, while possessing the other characteristics, dries without the usual gloss. Such varnish is usually called "flat varnish."

Enamel.—A special form of paint which, when spread in a thin film, flows out to a smooth coat and dries to a smooth, glossy, relatively hard, permanent solid when exposed to the air. An enamel always contains pigment and has considerable hiding power and color. Some enamels dry to a flat or eggshell finish instead of a gloss finish.

Filler.—A special kind of paint designed to be used for filling pores or other small breaks in the continuity of a surface preparatory to further treatment. When applied and exposed to the air, a filler should dry to a relatively hard, permanent, solid capable of properly supporting subsequent coats.

Toner.—An organic pigment which does not contain inorganic pigment or an inorganic carrying base.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

These definitions of terms, when adopted as standard, will become a part of the present Standard Definitions of Terms relating to Paint Specifications (Serial Designation: D 16 - 15), 1921 Book of A.S.T.M. Standards.

Lake.—A special type of pigment consisting essentially of an organic soluble coloring matter combined more or less definitely with an inorganic base or carrier, both together forming an insoluble pigment characterized generally by a bright color and a more or less pronounced translucency when made into an oil paint.

NOTE.—A more specific definition requires more extended description of the two (and perhaps three) types of pigment now generally classified as lakes. It would include (*a*) the older original type composed of hydrate of alumina dyed with a solution of the natural organic color, and (*b*) the more modern and far more extensive type made by precipitating from solution various coal tar colors by means of a metallic salt, tannin, or other suitable reagent, upon a base or carrier either previously prepared or coincidently formed. A number of lakes, combining both types in varying degree, might be regarded as a third class.

Drying Oil.—One which possesses to a marked degree the property of readily taking up oxygen from the air and changing to a relatively hard, tough, elastic substance when exposed to the air in thin films.

Semi-Drying Oil.—A semi-drying oil possesses the characteristics of a drying oil but to a lesser degree. There is no definite line of demarcation between drying and semi-drying oils.

Non-Drying Oils.—A non-drying oil does not of itself possess to a perceptible degree the power to take up oxygen from the air and lose its liquid characteristics.

TENTATIVE METHOD OF TEST
FOR
DISTILLATION OF GASOLINE, NAPHTHA, KEROSENE, AND SIMILAR PETROLEUM PRODUCTS.[1]

Serial Designation: D 86 – 21 T.

This method is issued under the fixed designation D 86; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

APPARATUS.

1. *Flask.*—The Standard 100-cc. Engler flask is shown in Fig. 1, the dimensions and allowable tolerance being as follows: **Flask.**

	Centimeters.	Inches.	Tolerances, cm.
Diameter of bulb, outside	6.5	2.56	0.2
" " neck, inside	1.6	0.63	0.1
Length of neck	15.0	5.91	0.4
" " vapor tube	10.0	3.94	0.3
Diameter of vapor tube, outside	0.6	0.24	0.05
" " " " inside	0.4	0.16	0.05
Thickness of vapor tube wall	0.1	0.04	0.05

The position of the vapor tube shall be 9 cm. (3.55 in.) ±3mm above the surface of the liquid when the flask contains its charge of 100 cc. The tube is approximately in the middle of the neck and set at an angle of 75 deg. (tolerance ±3 deg.) with the vertical.

2. *Condenser.*—The condenser (Fig. 2) consists of a $\frac{9}{16}$-in. (14.29 mm.) OD No. 20 Stubbs Gage seamless brass tube, 22 in. (55.88 cm.) long. It is set at an angle of 75 deg. from the perpendicular and is surrounded with a cooling bath 15 in. long (38.1 cm.), approximately 4 in. (10.16 cm.) wide by 6 in (15.24 cm.) high. The lower end of the condenser tube is cut off at an acute angle, and curved downward for a length of 3 in. (7.62 cm.) and slightly backward so as to insure contact with the wall of the graduate at a point 1 to $1\frac{1}{4}$ in. (2.54–3.175 cm.) below the top of the graduate when it is in position to receive the distillate. **Condenser.**

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

Shield. 3. *Shield.*—The shield (Fig. 2) is made of approximately 22 gage sheet metal and is 19 in. (48.26 cm.) high, 11 in. (27.94 cm.) long and 8 in. (20.32 cm.) wide, with a door on one narrow side, with two openings, 1 in. (2.54 cm.) in diameter, equally spaced, in each of the two narrow sides, and with a slot cut in one side for the vapor tube. The centers of these four openings are 8½ in. (21.59 cm.) below the top of the shield. There are also three ½-in. (1.27 cm.) holes in each of the four sides with their centers 1 in. (2.54 cm.) above the base of the shield.

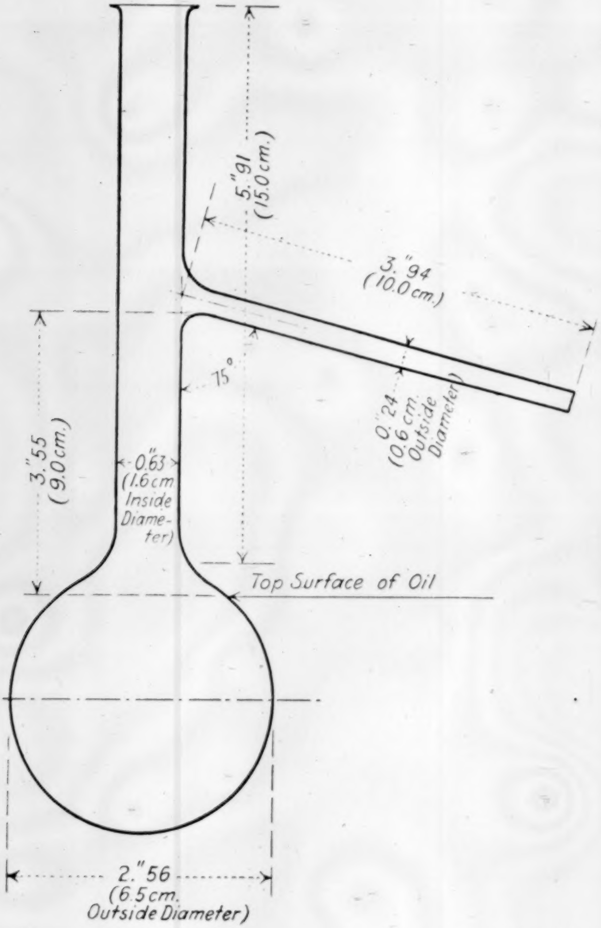
5."91
(15.0 cm.)
3."94
(10.0 cm.)
3."55
(9.0 cm.)
75°
0."24
(0.6 cm.
Outside
Diameter)
0."63
(1.6 cm
Inside
Diameter)
Top Surface of Oil
2."56
(6.5 cm.
Outside Diameter)

FIG. 1.

Support.

4. *Ring Support and Hard Asbestos Boards.*—The ring support is of the ordinary laboratory type, 4 in. (10.16 cm.) or larger in diameter, and is supported on a stand inside the shield. There are two hard asbestos boards: One 6 by 6 by $\frac{1}{4}$ in. (15.24 by 15.24 cm. by 6.35 mm.) with a hole $1\frac{1}{4}$ in. (3.175 cm.)[1] in diameter in its center, the sides of which shall be perpendicular to the surface; the other, an asbestos board to fit tightly inside the shield, with an opening 4 in. (10.16 cm.) in diameter concentric with the ring support. These are arranged as follows: The second asbestos board is placed on the ring and the first or smaller asbestos board on top so that it may be moved in accordance with the directions for placing the distilling flask. Direct heat is applied to the flask only through the $1\frac{1}{4}$-in. (3.175 cm.) opening in the first asbestos board.

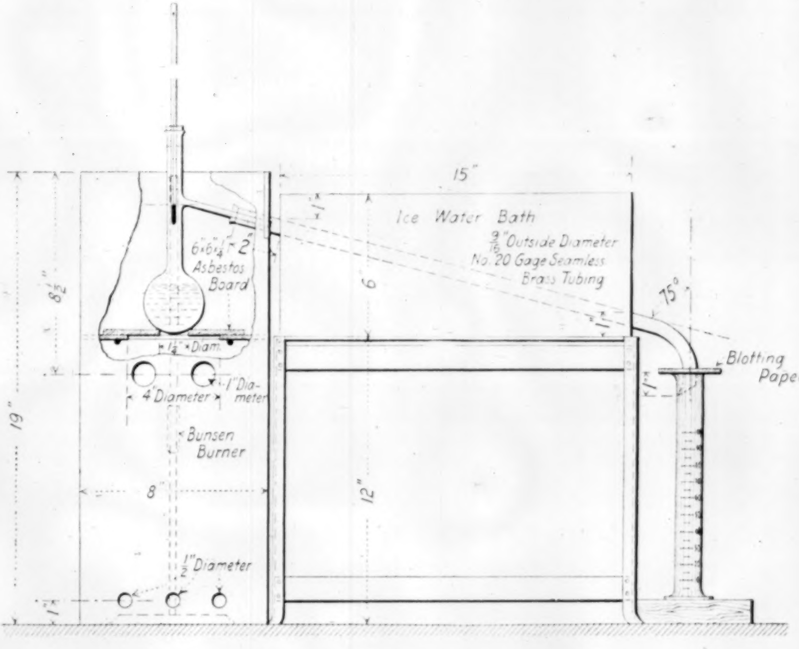
15"
Ice Water Bath
$\frac{9}{16}$" Outside Diameter
No. 20 Gage Seamless
Brass Tubing
75°
1"
1"
6"
6"×6"×$\frac{1}{4}$"
2"
Asbestos
Board
$8\frac{1}{2}$"
$1\frac{1}{4}$" Diam.
4" Diameter
1" Diameter
19"
Bunsen
Burner
8"
12"
$\frac{1}{2}$" Diameter
1"
Blotting
Paper
1"

FIG. 2

Heater.

5. *Gas Burner or Electric Heater.*—

(*a*) *Gas Burner.*—The burner is so constructed that sufficient heat can be obtained to distill the product at the uniform rate specified below. The flame should never be so large that it spreads over a circle of diameter greater than 3½ in. (8.89 cm.) on the under surface of the asbestos board. A sensitive regulating valve is a necessary adjunct, as it gives complete control of heating.

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[1] When distilling petroleum products having an end point above 470° F. (243°.34 C.), the hole in the asbestos board shall be $1\frac{1}{2}$ in. (3.81 cm.) in diameter.

(*b*) *Electric Heater.*—The electric heater, which may be used in place of the gas flame, shall be capable of bringing over the first drop within the time specified below when started cold, and of continuing the distillation at the uniform rate. The electric heater shall be fitted with an asbestos board top ⅛ to ¼ in. (3.175 to 6.35 mm.) thick, having a hole 1¼ in. (3.175 cm.) in diameter in the center. When an electric heater is employed, the portion of the shield above the asbestos board shall be the same as with the gas burner but the part below the board may be omitted.

Thermometer.

6. *Thermometers.*—

(*a*) A.S.T.M. Low Distillation Thermometer shall conform to the following specifications:

Type: Etched stem glass.
Total length: 381 mm.
Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.
Bulb: Corning Normal, Jena 16 III, or equally suitable thermometric glass.
Length, 10 to 15 mm.
Diameter, 5 to 6 mm.
Actuating liquid: Mercury.
Range: 30° F. to 580° F., or 0° C. to 300° C.
Immersion: Total.
Distance to 30° F. or 0° C. line from bottom of bulb: 100 to 110 mm.
Distance to 580° F. or 300° C. line from top of stem: 30 to 45 mm.
Filled: Nitrogen gas.
Top finish: Glass ring.
Graduation: All lines, figures and letters clear cut and distinct.
Scale graduated in 2° F., or 1° C. divisions and numbered every 20° F., or 10° C.; the first and each succeeding 10° F. (5° C.) line to be longer than the others.
Special markings: "A.S.T.M. Low Distillation," serial No. and manufacturer's trade mark etched on the stem.
Accuracy: Error at any point on scale shall not exceed one-half smallest scale division.
Test for permanency of range: After being subjected to a temperature of 560° F., or 290° C., for 24 hours the accuracy shall be within the limit specified.
Points to be tested for certification: 32°, 212°, 400°, 570° F., or 0°, 100°, 200°, 300° C.

(*b*) The A.S.T.M. High Distillation Thermometer shall conform to the following specifications:

Type: Etched stem glass.
Total length: 381 mm.
Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.

Bulb: Corning Normal, Jena 16 III, or equally suitable thermometric glass.
Length, 10 to 15 mm.
Diameter, 5 to 6 mm.
Actuating liquid: Mercury.
Range: 30° F. to 760° F., or 0° C. to 400° C.
Immersion: Total.
Distance to 30° F. or 0° C. line from bottom of bulb: 25 to 35 mm.
Distance to 760° F. or 400° C. line from top of stem: 30 to 45 mm.
Filled: Nitrogen gas.
Top finish: Glass ring.
Graduation: All lines, figures and letters clear cut and distinct.
Scale graduated in 2° F., or 1° C., divisions and numbered every 20° F., or 10° C.; the first and each succeeding 10° F. (5° C.) line to be longer than the others.
Special markings: A.S.T.M. High Distillation. Serial No. and manufacturer's name or trade mark etched on the stem.
Accuracy: Error at any point on scale shall not exceed one smallest scale division up to 700° F., or 370° C.
Test for permanency of range: After being subjected to a temperature of 700° F., or 370° C., for 24 hours the accuracy shall be within the limit specified.
Points to be tested for certification: 32°, 212°, 400°, 700° F., or 0°, 100°, 200°, 370° C.

Graduate.

7. *Graduate.*—The graduate shall be of the cylindrical type, of uniform diameter, with a pressed or molded base and a lipped top. The cylinder shall be graduated to contain 100 cc., and the graduated portion shall be not less than 7 in. (17.78 cm.) nor more than 8 in. (20.32 cm.) long. It shall be graduated in single cubic centimeters and each fifth mark shall be distinguished by a longer line. It shall be numbered from the bottom up at intervals of 10 cc. The distance from the 100-cc. mark to the rim shall be not less than $1\frac{1}{4}$ in. (3.175 cm.) nor more than $1\frac{3}{4}$ in. (4.445 cm.). The graduations shall not be in error by more than 1 cc. at any point on the scale.

PROCEDURE.

Procedure.

8. (*a*) The condenser bath shall be filled with cracked ice,[1] and enough water added to cover the condenser tube. The temperature shall be maintained between 32 and 40° F. (0 and 4°.45 C.).

(*b*) The condenser tube shall be swabbed to remove any liquid remaining from the previous test. A piece of soft cloth attached to a cord or copper wire may be used for this purpose.

(*c*) The bulb of the distillation thermometer shall be covered uniformly with a long-fiber absorbent cotton weighing not less than 3 nor more than 5 mg. A fresh portion of clean cotton shall be used for each distillation.

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[1] Any other convenient cooling medium may be used.

(*d*) One hundred cubic centimeters of the product shall be measured in the 100-cc. graduated cylinder at 55 to 65° F. (12.78 to 18°.33 C.) and transferred directly to the Engler flask. None of the liquid shall be permitted to flow into the vapor tube.

(*e*) The thermometer[1] provided with a cork shall be fitted tightly into the flask so that it will be in the middle of the neck and so that the lower end of the capillary tube is on a level with the inside of the bottom of the vapor outlet tube at its junction with the neck of the flask.

(*f*) The charged flask shall be placed in the $1\frac{1}{4}$-in. (3.175-cm.) opening in the 6 by 6-in. (15.24 by 15.24-cm.) asbestos board with the vapor outlet tube inserted into the condenser tube. A tight connection may be made by means of a cork through which the vapor tube passes. The position of the flask shall be so adjusted that the vapor tube extends into the condenser tube not less than 1 in. (2.54 cm.) nor more than 2 in. (5.08 cm.).

(*g*) The graduated cylinder used in measuring the charge shall be placed, without drying, at the outlet of the condenser tube in such a position that the condenser tube shall extend into the graduate at least 1 in. (2.54 cm.) but not below the 100-cc. mark. Unless the temperature is between 55 and 65° F. (12.78 and 18°.33 C.) the receiving graduate shall be immersed up to the 100-cc. mark in a transparent bath maintained between these temperatures. The top of the graduate shall be covered closely during the distillation with a piece of blotting paper or its equivalent, cut so as to fit the condenser tube tightly.

Distillation.

9. When everything is in readiness, heat shall be applied at a uniform rate, so regulated that the first drop of condensate falls from the condenser in not less than 5 nor more than 10 minutes. When the first drop falls from the end of the condenser the reading of the distillation thermometer shall be recorded as the *initial boiling point.* The receiving cylinder shall then be moved so that the end of the condenser tube shall touch the side of the cylinder. The heat shall then be so regulated that the distillation will proceed at a uniform rate of not less than 4 nor more than 5 cc. per minute. The reading of the distillation thermometer shall be recorded when the level of the distillate reaches each 10-cc. mark on the graduate.

After the 90-per-cent point has been recorded, the heat may be increased because of the presence of the heavy ends which have high boiling points. However, no further increase of heat should be applied after this adjustment. The 4 to 5-cc. rate can rarely be maintained from the 90-per-cent point to the end of the distillation, but in no case should the period between the 90-per-cent and the end point be more than five minutes.

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[1] For products having an initial boiling point of 212° F. (100° C.) or higher, the High Distillation Thermometer shall be used; for all other products, the Low Distillation Thermometer shall be used.

The heating shall be continued until the mercury reaches a maximum and starts to fall consistently. The highest temperature observed on the distillation thermometer shall be recorded as the *maximum temperature* or end point. Usually this point will be reached after the bottom of the flask has become dry.

The total volume of the distillate collected in the receiving graduate shall be recorded as the *recovery*.

The cooled residue shall be poured from the flask into a small cylinder graduated in 0.1 cc., measured when cool and the volume recorded as *residue*.

The difference between 100 cc. and the sum of the recovery and the residue shall be calculated and recorded as *distillation loss*.

ACCURACY.

10. With proper care and attention to detail, duplicate results obtained for initial boiling point and maximum temperature, respectively, should not differ from each other by more than 6° F. (3°.33 C.). **Accuracy.**

TENTATIVE METHOD OF TEST

FOR

MELTING POINT OF PARAFFIN WAX.[1]

Serial Designation: D 87 – 21 T.

This method is issued under the fixed designation D 87; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

DEFINITION.

Definition. 1. The A.S.T.M. Paraffin Wax Melting Point[2] is the temperature at which melted paraffin wax, when allowed to cool under definite specified conditions, first shows a minimum rate of temperature change.

APPARATUS.

Containers. 2. *Wax Container.*—Test tube of standard form, 25 mm. (1 in.) outside diameter and 100 mm. (4 in.) long. It may be marked with a filling line, 2 in. above the bottom. This test tube shall be closed by a tightly fitting cork having two openings, one at the center for the melting point thermometer and the other for a stirrer at one side of the center. The opening for the stirrer may be lined with glass or metal tubing to act as a guide for the stirrer.

Air Bath. 3. *Air Bath.*—Suitable water-tight cylinder, 2 in. in inside diameter and 4½ in. deep. This air bath shall be provided with a tightly fitting cork having a central opening for holding the test tube firmly in a vertical position in the center of the air bath.

Water Bath. 4. *Water Bath.*—Suitable cylinder, 5⅛ in. in inside diameter and 6 in. deep. This water bath shall be provided with a suitable cover and with the guides and fasteners necessary to hold the air bath firmly in a vertical central position so that the sides and bottom of the air bath shall be surrounded by a layer of water 1½ in. thick. The water bath cover shall have a slot for introduction of a suitable stirrer and shall have an opening for the bath thermometer so that the latter may be suspended in a vertical position $\frac{3}{4}$ in. from the outside wall of the water bath. Air bath, water bath and water bath cover may be conveniently made of metal in one assembly as shown in Fig. 1.

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[2] The so-called "American Melting Point" is an arbitrary figure 3° F. higher than the A.S.T.M. Paraffin Wax Melting Point.

Stirrer.

5. *Stirrer in test tube.*—Brass or copper wire, $\frac{1}{8}$ in. in diameter and about 12 in. long. A circular loop, $\frac{1}{2}$ in. in diameter, shall be formed at one end of this wire in such a manner that the loop lies in a horizontal plane when the rest of the wire is in a vertical position. The stirrer thus formed shall be passed through the proper opening in the test-tube cork and the upper end may then be bent into a shape convenient for holding.

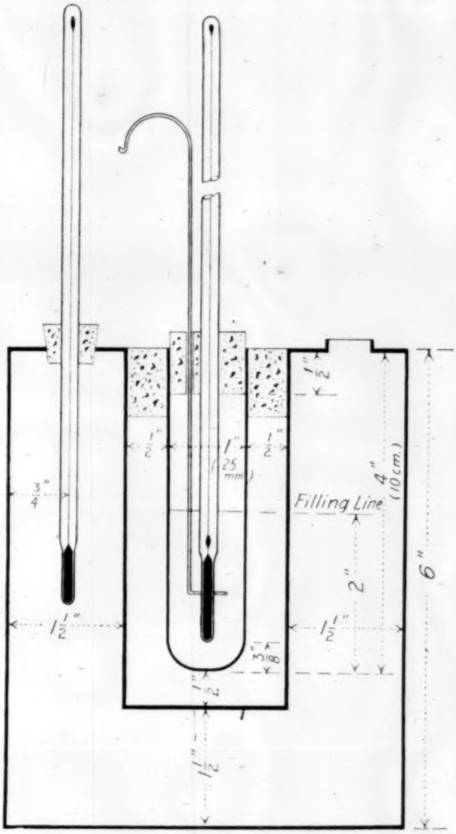

FIG. 1.—Apparatus for Determination of Melting Point of Paraffin Wax.

6. *Thermometer.*—The A.S.T.M. Paraffin Wax Melting Point thermometer shall conform to the following specifications:

Type: Etched stem glass.
Total Length: 368 mm.
Stem: Plain front, enamel back, suitable thermometer tubing. Diameter, 6 to 7 mm.
Bulb: Corning Normal, Jena 16 III or equally suitable thermometric glass. Length, maximum, 28 mm. Diameter not greater than stem.
Actuating liquid: Mercury.
Range: 80° to 160° F.
Immersion: $3\frac{1}{8}$-in. The words "$3\frac{1}{8}$-in. Immersion" shall be etched on the stem and also a line around the stem to indicate the depth of immersion.
Distance to 80° line from bottom of bulb: 105 to 115 mm.
Distance to 160° line from top of stem: 25 to 40 mm.
Contraction chamber: Top to be not more than 41 mm. from bottom of bulb.
Expansion chamber: To hold 212° F.
Filled: Nitrogen gas.
Top finish: Plain.
Graduation: All lines, figures and letters to be clean cut and distinct. Scale graduated in 0°.2 F. and numbered every 2° F., every full degree line to be longer than the others.
Special markings: "A.S.T.M. Pffe. M. P." Serial No. and manufacturer's name or trade mark etched on the stem.
Accuracy: Error at any point on scale shall not exceed one smallest scale division.
Points to be tested for certification: 80°, 100°, 120°, 140°, 160° F.

Bath Thermometer. 7. Bath thermometer of any suitable type, accurate to 2° F. throughout the required range.

PROCEDURE.

Procedure. 8. An average sample of the wax to be tested shall be melted in a suitable container in a water bath whose temperature shall be not more than 35° F. above the approximate melting point of the wax sample. Direct heat, such as a flame or hot plate, shall not be used and the wax sample shall not be held in the melted condition any longer than necessary.

The test tube shall be filled with melted wax to a height of 2 in. The test-tube cork, carrying the stirrer and the melting point thermometer with the $3\frac{1}{8}$-in. immersion line at the under surface of the cork, shall be inserted into the test tube for a distance of $\frac{1}{2}$ in. The lower end of the thermometer bulb shall then be $\frac{3}{8}$ in. from the bottom of the test tube.

The air bath being in its proper position in the water bath, the latter shall be filled to within $\frac{1}{2}$ in. of the top with water at a temperature 15 to 20° F. below the approximate melting point of the wax sample.

The test tube containing the melted wax, with wax stirrer and thermometer in place, shall be inserted into the air bath in a central vertical position so that the bottom of the test tube is ½ in. from the bottom of the air bath. The temperature of the water bath shall be adjusted by stirring if necessary, so that it shall be lower than the temperature of the wax sample by not more than 30° F. and not less than 25° F., when the wax sample has cooled to a temperature 10° F. above its approximate melting point.

When these conditions have been obtained, temperature adjustment and stirring of the water bath shall be discontinued. The wax shall be stirred continuously during the remainder of the test, the stirring loop being moved up and down throughout the entire length of the test tube in a steady motion at the rate of 20 complete cycles per minute. The melting point thermometer reading, estimated to 0°.1 F. shall be observed and recorded every 30 seconds. The temperature of the wax will fall gradually at first, will then become almost constant and will then again fall gradually.

The melting point thermometer reading, estimated to 0°.1 F., shall be observed and recorded every 30 seconds, for at least three minutes after the temperature again begins to fall after remaining almost constant. The record of temperature readings shall then be inspected and the average of the first four readings that lie within a range of 0°.2 F. shall be considered as the uncorrected melting point. This temperature shall be corrected if necessary for error in the thermometer scale and the corrected temperature shall be reported as the "A.S.T.M. Paraffin Wax Melting Point."

ACCURACY.

9. Duplicate determinations on the same sample should differ by not more than 0°.2 F. **Accuracy.**

TENTATIVE METHOD OF TEST
FOR
VISCOSITY OF FUEL OILS AND OTHER OILS OF SIMILAR VISCOSITY.[1]

Serial Designation: D 88 – 21 T.

This method is issued under the fixed designation D 88; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Viscosimeter. 1. Viscosity shall be determined by means of the Saybolt Furol Viscosimeter.

Apparatus. 2. The apparatus and method of operation shall be the same as for the Standard Saybolt Universal Viscosimeter as given in Section 6 of the Standard Methods of Testing Lubricants (Specific Gravity, Free Acid, Carbon Residue, Viscosity) (Serial Designation: D 47) of the American Society for Testing Materials,[2] all dimensions being the same except the diameter of the outlet tube which shall be as follows:

	MINIMUM.	NORMAL.	MAXIMUM.
Inside diameter of outlet tube, cm..........	0.313	0.315	0.317
Outside diameter at lower end, cm..........	0.40	0.43	0.46

Viscosity. 3. Viscosity shall be determined at 122° F. (50° C.) and shall be expressed as — seconds, Saybolt Furol, being the time in seconds for the delivery of 60 cc. of oil.

Temperature of Testing. 4. Oil showing a time of less than 25 seconds, Saybolt Furol, at 122° F., shall be tested on the Saybolt Universal at 122° F. Oil showing a time of less than 32 seconds Saybolt Universal, at 122° F. shall be measured in the Saybolt Universal at 100° F. (37°.8 C.). This test does not apply to fuels, having a viscosity at 100° F. of less than 32 seconds, Saybolt Universal, which are not considered to be fuel oils.

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[2] 1921 Book of A.S.T.M. Standards.

TENTATIVE METHOD OF TEST
FOR
DETECTION OF FREE SULFUR AND CORROSIVE SULFUR COMPOUNDS IN PETROLEUM PRODUCTS.[1]

Serial Designation: D 89 - 21 T.

This method is issued under the fixed designation D 89; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Scope.

1. This method of test is applicable for the detection of free sulfur and corrosive sulfur compounds in oil.

Procedure.

2. (*a*) A clean strip of mechanically polished pure sheet copper about $\frac{1}{2}$ in. wide and 3 in. long shall be put into a sample of the oil contained in a clean test tube about half the length of the copper strip being submerged. The test tube shall then be closed with a stopper (venting where volatile liquids are being tested) and left to stand over night at a temperature of 150° F.

(*b*) At the end of this time the copper strip shall be removed and washed free from oil with gasoline. It shall then be compared with a similar strip of copper freshly polished in a similar manner.

Detection of Sulfur.

3. If free sulfur or corrosive sulfur compounds are present in the oil the copper test strip will appear discolored when compared with the freshly cleaned copper.

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TENTATIVE METHOD OF TEST

FOR

SULFUR IN NAPHTHAS AND ILLUMINATING OILS.[1]

Serial Designation: D 90 - 21 T.

This method is issued under the fixed designation D 90; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

APPARATUS.

Absorber of chemically resistant glass, about 150-cc. capacity, containing glass beads or short pieces of glass rod in the suction side as shown.

Chimney of chemically resistant glass connected with the absorber by a rubber stopper.

Spray trap of chemically resistant glass connected with the absorber by a rubber stopper.

Small lamp of about 25-cc. capacity. This lamp may conveniently consist of a 25 to 35-cc. Erlenmeyer flask and a cork carrying a short section of glass tubing, about $\frac{1}{8}$ in. in inside diameter. The cork must be grooved along the sides so that air may enter the flask while the oil is being consumed.

Ordinary cotton wicking.

Filter pump or other means for continuous suction and rubber tubing to connect with spray trap.

SOLUTIONS REQUIRED.

Hydrochloric acid.—Solution containing 2.275 g. HCl per liter and carefully checked for accuracy.

Sodium carbonate.—Solution containing 3.306 g. Na_2CO_3 per liter. Exactly 10.0 cc. should be required to neutralize 10.0 cc. of the hydrochloric acid solution.

Methyl orange.—Solution in distilled water, containing 0.004 g. methyl orange per liter.

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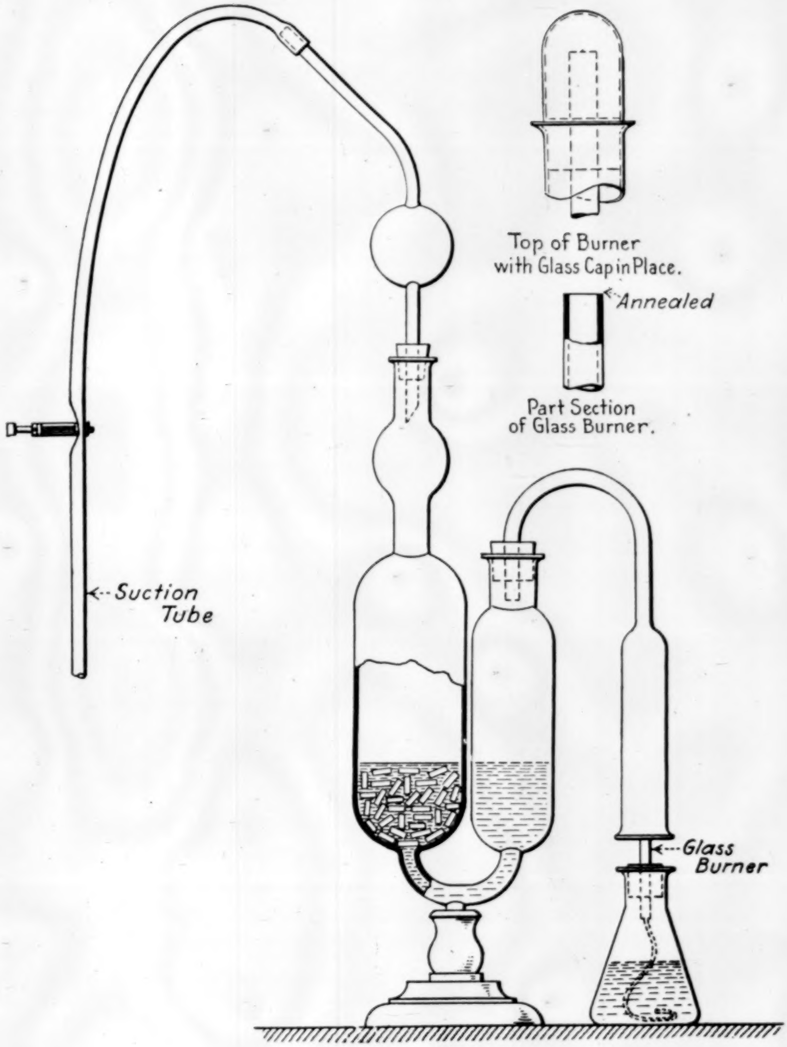
Top of Burner
with Glass Cap in Place.
Annealed
Part Section
of Glass Burner.
Suction
Tube
Glass
Burner

FIG. 1.—Apparatus for Determination of Sulfur in Oils.

TENTATIVE METHOD OF TEST
FOR
SULFUR IN NAPHTHAS AND ILLUMINATING OILS.[1]

Serial Designation: D 90 - 21 T.

This method is issued under the fixed designation D 90; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

APPARATUS.

Absorber of chemically resistant glass, about 150-cc. capacity, containing glass beads or short pieces of glass rod in the suction side as shown.

Chimney of chemically resistant glass connected with the absorber by a rubber stopper.

Spray trap of chemically resistant glass connected with the absorber by a rubber stopper.

Small lamp of about 25-cc. capacity. This lamp may conveniently consist of a 25 to 35-cc. Erlenmeyer flask and a cork carrying a short section of glass tubing, about $\frac{1}{8}$ in. in inside diameter. The cork must be grooved along the sides so that air may enter the flask while the oil is being consumed.

Ordinary cotton wicking.

Filter pump or other means for continuous suction and rubber tubing to connect with spray trap.

SOLUTIONS REQUIRED.

Hydrochloric acid.—Solution containing 2.275 g. HCl per liter and carefully checked for accuracy.

Sodium carbonate.—Solution containing 3.306 g. Na_2CO_3 per liter. Exactly 10.0 cc. should be required to neutralize 10.0 cc. of the hydrochloric acid solution.

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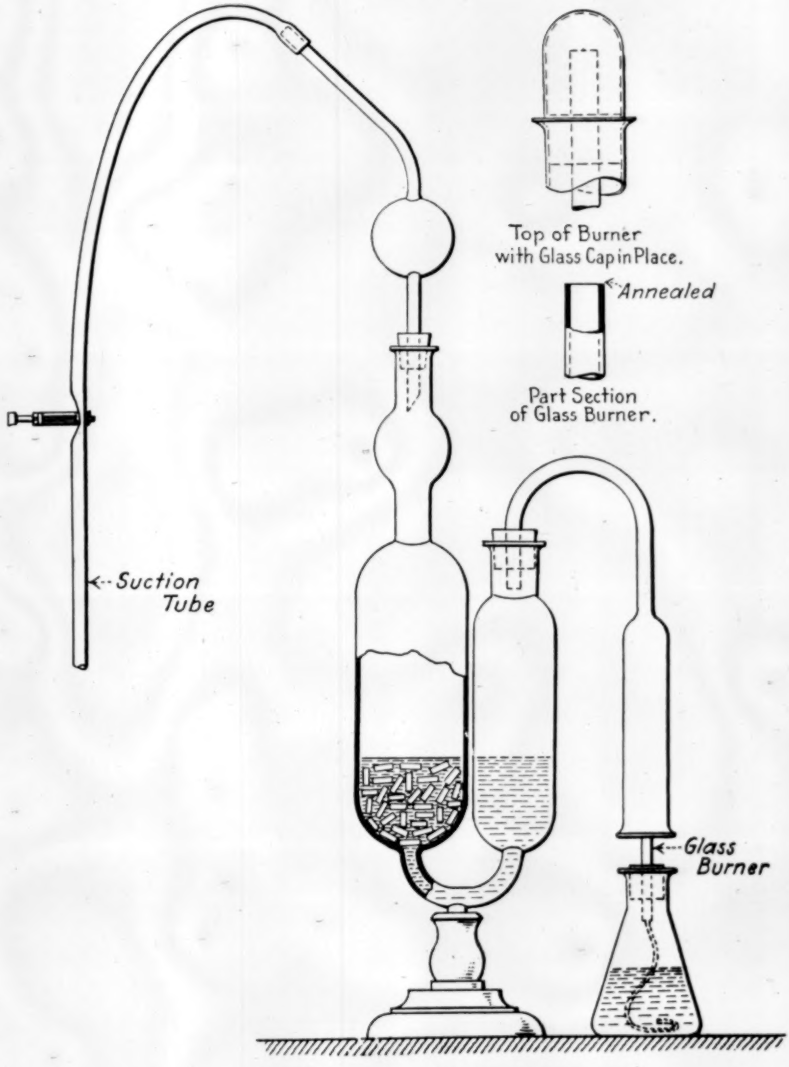
Top of Burner
with Glass Cap in Place.
Annealed
Part Section
of Glass Burner.
Suction
Tube
Glass
Burner

FIG. 1.—Apparatus for Determination of Sulfur in Oils.

PROCEDURE.

Pass two strands of new cotton wicking about 4.5 in. long through the $\frac{1}{8}$-in. diameter wick tube so that they are not twisted but parallel in the wick tube. Trim the wick with very sharp scissors. Pour into the clean dry lamp about 20 cc. of the oil to be tested, insert the wick and cork and weigh the assembly with an accuracy of 0.001 g. It is advisable to make a blank determination at the same time and under the same conditions by burning sulfur-free alcohol in a similar lamp.

Rinse out the absorber containing the glass beads thoroughly with distilled water and add exactly 10.0 cc. of the standard sodium carbonate solution from an accurately calibrated burette, allowing the burette to drain for three minutes before taking the reading. Rinse the chimney and the spray trap with distilled water, dry the chimney and connect both to the absorber as shown in Fig. 1. Set up the apparatus for the blank determination in exactly the same manner and using exactly 10.0 cc. of the sodium carbonate solution. Apply gentle suction to both absorbers, light both the weighed oil lamp and alcohol lamp and then place in position under the chimneys so that the tops of the wick tubes extend into the chimneys not more than $\frac{1}{16}$ in. Adjust the wick height and the suction so that the flame is steady, free from smoke and approximately $\frac{1}{4}$ in. high. This requires that the wick be flush with the top of the wick tube for naphthas and a little higher for illuminating oils. The room must be free from drafts. The suction on the blank should be so adjusted that air is drawn through both determinations at the same rate. Continue burning for about two hours, or less if the sulfur content of the oil is high. During this time the oil should be consumed at the rate of about 1 g. per hour.

Extinguish the flames and stop the suction on both absorbers. Weigh the oil lamp immediately and calculate by difference the weight of oil consumed. Working with the blank first, disconnect the spray trap and chimney and wash them thoroughly with the methyl orange solution, using a wash bottle with a very fine jet and collecting the washings in the absorber. The amount of solution required for washing should not exceed 35 cc. Carefully titrate the very faintly yellowish solution in the absorber with standard HCl, added to the suction side of the absorber from an accurately calibrated burette. During this titration, the contents of the absorber should be agitated carefully, either by blowing through a rubber tube held between the operator's lips and connected at the other end with the chimney side of the absorber or else by the use of a suitable rubber syringe bulb.

As the end point is approached, draw the liquid back into the chimney side between each addition of acid and then blow it into the suction side, agitating as before. As soon as the first permanent pink color appears, the end point has been reached. Read and record the volume of HCl solution used.

Rinse the chimney and spray trap used in the actual determination into the absorber to which they were connected, exactly as prescribed for the blank. If the methyl orange solution in the absorber has a pink color, too much oil has been burned and the determination must be repeated, burning for a shorter time. Titrate just as in the blank, making sure that the absorber is cold. Read and record the volume of HCl solution required.

Calculate the sulfur content of the oil by substituting the proper values in the following formula:

$$\text{Percentage of Sulfur} = \frac{(\text{HCl for blank, cc.} - \text{HCl for sample, cc.}) \times 0.1}{\text{grams of oil burned}}.$$

If a blank is not run, the formula is:

$$\text{Percentage of Sulfur} = \frac{(\text{Na}_2\text{CO}_3\text{, cc.} - \text{HCl, cc.}) \times 0.1}{\text{grams of oil burned}}.$$

These formulas are correct only for the standard solutions specified, 1 cc. of each being equivalent to 0.001 g. of sulfur. The use of solutions of any other strength, such as N/10, involves more complicated calculation and is not advisable.

TENTATIVE METHOD OF TEST
FOR
PRECIPITATION NUMBER OF LUBRICATING OILS.[1]

Serial Designation: D 91 - 21 T.

This method is issued under the fixed designation D 91 ; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. This method is commonly used for steam cylinder stocks and black oils and may be used for other lubricating oils.

DEFINITION.

Definition. 2. The A.S.T.M. Precipitation Number is the number of cubic centimeters of precipitate formed when 10 cc. of lubricating oil are mixed with 90 cc. of petroleum naphtha of definite quality and centrifuged under definite prescribed conditions.

APPARATUS.

Centrifuge. 3. *Centrifuge.*—The centrifuge shall be capable of whirling at least two 100-cc. centrifuge tubes filled with water at the required speed. It shall be of sound design and rugged construction so that it may be operated without danger. The tube carriers shall be so designed that the glass centrifuge tubes may be cushioned with water, rubber or other suitable material. The tube holders shall be surrounded during the operation by a suitable metal shield or case, strong enough to eliminate danger if any breakage occurs.

Preferred forms of centrifuge shall have a diameter of swing (tip to tip of whirling tubes) of 15 to 17 in. and a speed of at least 1500 r.p.m. or equivalent. If the available centrifuge has a diameter of swing varying from these limits, it shall be run at the proper speed to give the same centrifugal force at the tips of the tubes as that obtained with the preferred form of centrifuge. The proper speed shall be calculated from the following formula in which D represents the diameter of swing (tip to tip of whirling tubes) of the centrifuge used:

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

$$\text{R.p.m.} = 1500 \sqrt{\frac{16}{D}}$$

Centrifuge Tubes. 4. *Centrifuge tubes, A.S.T.M. type.*—These tubes shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 cc. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of tube as follows:

RANGE.	SCALE DIVISIONS.	LIMIT OF ERROR.	NUMBERED.
0 - 3 cc.	0.1 cc.	0.05 cc.	1, 2, 3 cc.
3 - 5 "	0.5 "	0.2 "	4, 5 "
5 - 10 "	1.0 "	0.5 "	6, 8, 10 "
10 - 25 "	5.0 "	1.0 "	15, 20, 25 "
50 - 100 "	50.0 "	1.0 "	50, 100 "

The shape is optional provided it does not conflict with the other requirements.

Diluent. 5. Petroleum naphtha meeting the following requirements shall be used for the diluent.

Specific gravity at 60° F., 0.695–0.705.
Initial Boiling Point, A.S.T.M., 113–131° F. (45–55° C.).
End Point, A.S.T.M., not higher than 248° F. (120° C.).

PROCEDURE.

Preparing for Centrifuging. 6. Exactly 10.0 cc. of the oil to be tested shall be measured in each of two clean and dry centrifuge tubes at room temperature. Each tube shall be filled to the 100-cc. mark with the prescribed diluent and closed tightly with a softened cork (not a rubber stopper). Each tube shall then be inverted at least 20 times, allowing the liquid to drain thoroughly from the tapered tip of the tube each time. The tubes shall then be placed in a water bath at 90 to 95° F. for five minutes. The corks shall be momentarily removed to relieve any pressure and each tube shall again be inverted at least 20 times exactly as before. The success of this method depends to a large degree upon having a thoroughly homogeneous mixture which will drain quickly and completely from the tapered tip when the tube is inverted.

Centrifuging. 7. The two centrifuge tubes shall then be placed in the centrifuge on opposite sides and shall be whirled at a rate of 1400 to 1500 r.p.m. or equivalent for 10 minutes. The volume of sediment at the bottom of each tube shall be read and recorded, estimating to 0.05 cc. if possible. The tubes shall then be replaced in the centrifuge, again whirled for 10 minutes as before, and removed for reading the volume of the sediment as before. This operation shall be repeated until the volume of sediment in each tube remains constant for three consecutive readings. In general, not more than four whirlings are required.

Precipitation Number.

8. The volume of the solid sediment at the bottom of each centrifuge tube shall be read, estimating to 0.1 cc. or closer if possible. If the two readings differ by not more than 0.1 cc. the mean of the two shall be reported as the "A.S.T.M. Precipitation Number." If the two readings differ by more than 0.1 cc. two more determinations shall be made and the average of the four determinations shall be reported.

ACCURACY.

Accuracy.

9. With care and proper attention to details, duplicate determinations of Precipitation Number by this method should not differ by more than 0.1, provided the centrifuge tubes are accurate and readable to this degree.

TENTATIVE METHOD OF TEST
FOR
FLASH AND FIRE POINTS BY MEANS OF OPEN CUP.[1]

Serial Designation: D 92 – 21 T.

This method is issued under the fixed designation D 92; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

1. The open cup flash and fire test on all products except fuel oils and those having an open cup flash below 175° F. shall be determined in the Cleveland Open Cup. **Scope.**

APPARATUS.

2. The flash cup proper shall be made of brass and shall have the following dimensions: **Flash Cup.**

	INCHES.		CENTIMETERS.	
	DIMENSIONS.	TOLERANCES.	DIMENSIONS.	TOLERANCES.
Inside diameter	$2\frac{1}{2}$	$\pm\frac{1}{32}$	6.350	±0.079
Outside diameter	$2\frac{11}{16}$	$\pm\frac{1}{32}$	6.826	±0.079
Inside height	$1\frac{5}{16}$	$\pm\frac{1}{32}$	3.334	±0.079
Thickness of bottom	$\frac{1}{8}$	$\pm\frac{1}{64}$	0.318	±0.040
Depth of filling mark below top of cup	$\frac{3}{8}$	$\pm\frac{1}{64}$	0.953	±0.040

The cup shall be heated by contact with a metal plate $\frac{1}{4}$ in. (0.635 cm.) thick and 6 in. (15.24 cm.) wide. (The plate may be of any suitable metal and may be either circular or square.) In the center of the plate there shall be a plane depression $\frac{1}{32}$ in. (0.079 cm.) deep and of diameter just sufficient to fit the cup. The plate shall be covered with a sheet of hard asbestos board $\frac{1}{4}$ in. (0.635 cm.) thick and of the same shape as the metal plate. There shall be cut in the center of the asbestos board a circular hole just fitting the cup. The metal plate may be heated in any convenient manner. The use of a gas burner, electric heater, or alcohol lamp is permitted. If a flame heater is used it may be protected from drafts or excessive radiation by any suitable type of shield that does not project above the level of the upper surface of the asbestos board.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

Thermometer. 3. The thermometer shall conform to the following specifications:

Type: Etched stem glass.
Total length: 305 mm.
Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.
Bulb: Corning Normal, Jena 16 III, or equally suitable thermometric glass.
Length, 13 mm. maximum.
Diameter, not greater than stem.

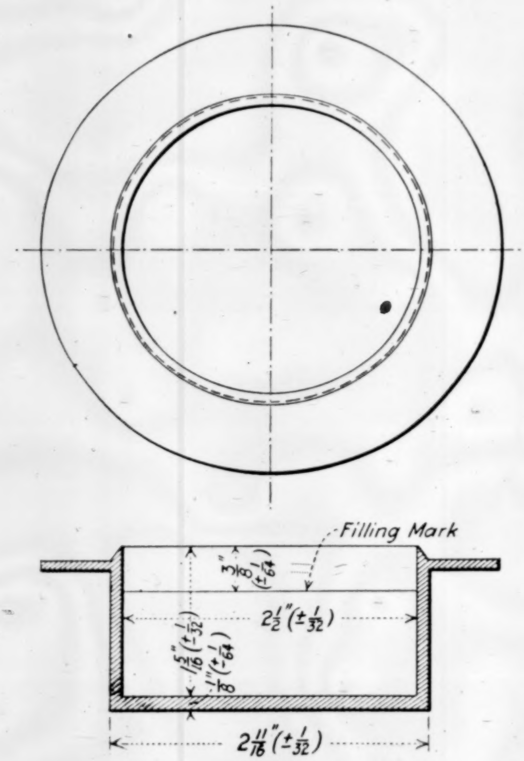

FIG. 1.—Cleveland Open Cup.

Actuating liquid: Mercury.
Range: +20° to +760° F.
Immersion: One inch. The words "1-in. Immersion" shall be etched on the stem and also a line around the stem to indicate the depth of immersion.
Distance to 20° line from bottom of bulb: 40 to 50 mm.
Distance to 760° line from top of stem: 30 to 45 mm.
Filled: Nitrogen gas.
Top finish: Red glass ring.

Graduation: **All lines, figures and letters clear cut and distinct.**
Scale graduated in 5° divisions.
Scale numbered every 20°, the first and each succeeding 10° F. line to be longer than the others.

Special Marking: **"A.S.T.M. Open Flash," serial number and manufacturer's name** or trade mark etched on stem.

Accuracy: **Error at any point on scale shall not exceed one-half smallest scale division up to 700° F.**

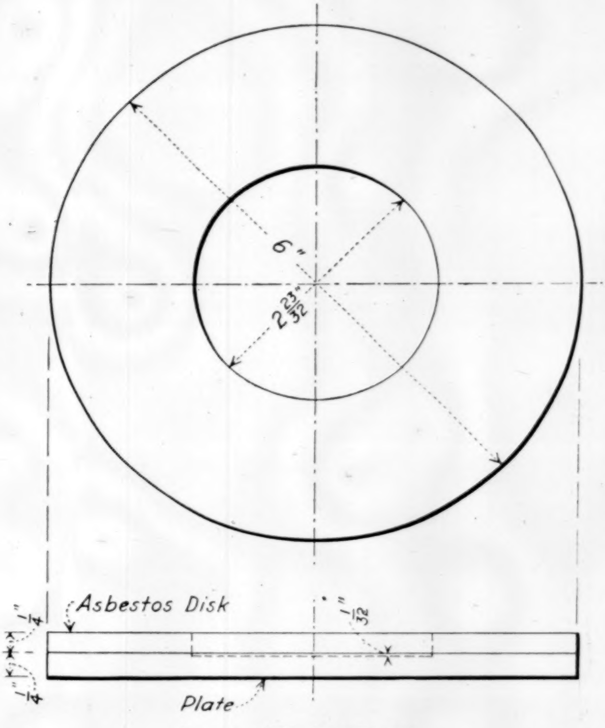

FIG. 2.—Heating Plate.

Test for permanency of range: **After being subjected to a temperature of 700° F. for 24 hours the accuracy shall be within the limit specified.**

Points to be tested for certification: 32°, 212°, 400°, 700° F.

PROCEDURE.

4. (*a*) The thermometer shall be suspended or held in a vertical position by any suitable device. The bottom of the bulb shall be $\frac{1}{4}$ in. (0.635 cm.)[1] from the bottom of the cup, and above a point half way between the center and back of the cup. **Procedure.**

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[1] **The immersion line engraved on the thermometer stem will be $\frac{1}{16}$ in. (0.159 cm.) below the level of the rim of the cup.**

(*b*) The cup shall be filled with the oil to be tested in such a manner that the top of the meniscus is exactly at the filling line at room temperature. The surface of the oil shall be free from bubbles. There shall be no oil above the filling line or on the outside of the apparatus.

(*c*) The test flame shall be approximately $\frac{5}{32}$ in. (0.397 cm.) in diameter.

NOTE.—For purposes of comparison it is recommended that a bead of suitable light colored material be mounted in a convenient position so that the size of the test flame can be determined. The device for applying the flame may be of any suitable type but it is suggested that the tip be approximately $\frac{1}{16}$ in. (0.159 cm.) in diameter at the end and that the orifice be $\frac{1}{32}$ in. (0.079 cm.) in diameter. If the device for operating the test flame be mounted in such a manner as to permit automatic duplication of the sweep of the test flame the radius of swing shall be not less than 6 in.

(*d*) The test flame shall be applied as the temperature read on the thermometer reaches each successive 5° F. mark. The flame shall pass in a straight line (or on the circumference of a circle having a radius of at least 6 in.) across the center of the cup and at right angles to the diameter passing through the thermometer. The test flame shall, while passing across the surface of the oil, be in the plane of the upper edge of the cup. The time for the passage of the test flame across the cup shall be approximately one second.

(*e*) The rate of heating of the oil shall be such that the temperature read on the thermometer increases not less than 9 nor more than 11° F. per minute.

Flash Point. 5. The flash point shall be taken as the temperature read on the thermometer when a flash appears at any point on the surface of the oil. The true flash must not be confused with a bluish halo that sometimes surrounds the test flame.

Fire Point. 6. After determining the flash point the heating shall be continued at the specified rate, and application of the test flame shall be made at the specified intervals until the oil ignites and continues to burn for a period of at least five seconds. The temperature read when this occurs shall be taken as the fire point.

Precautions. 7. The flash point and fire point tests shall be made in a room or compartment free from air drafts. The operator shall avoid breathing over the surface of the oil. It is desirable that the room or compartment be darkened sufficiently so that the flash may be readily discernible.

TENTATIVE METHOD OF TEST
FOR
FLASH POINT BY MEANS OF THE PENSKY-MARTENS CLOSED TESTER.[1]

Serial Designation: D 93 - 21 T.

This method is issued under the fixed designation D 93 ; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. The A.S.T.M. standard Pensky-Martens closed tester shall be used for determining the flash point of fuel oil unless the use of the Tag closed tester is specified.

APPARATUS.

Pensky-Martens Tester. 2. The Pensky-Martens tester, a diagram of which appears in Fig. 1, shall include the following major parts:

Cup.—The cup of the A.S.T.M. Pensky-Martens flash tester shall be made of brass and shall satisfy the following dimensional specifications:

	INCHES.			CENTIMETERS.		
DIMENSIONS.	MINIMUM.	NORMAL.	MAXIMUM.	MINIMUM.	NORMAL.	MAXIMUM
Inside diameter below filling mark	1.950	2.000	2.050	4.953	5.080	5.207
Difference, inside and outside diameters below filling mark	0.120	0.125	0.130	0.305	0.318	0.330
Inside height	2.150	2.200	2.250	5.461	5.588	5.715
Thickness of bottom	0.070	0.095	0.120	0.178	0.241	0.305
Distance from rim to filling mark	0.845	0.860	0.875	2.146	2.184	2.223
Distance lower surface flange to bottom of cup	1.780	1.795	1.810	4.521	4.559	4.597

The inside of the cup may be turned to a slightly larger diameter above the filling mark and the outside may be tapered above the flange but the wall thickness at the upper edge shall be not less than 0.04 in. (0.102 cm.). The flange should be approximately 0.5 in. (1.27 cm.) wide and approximately 0.125 in. (0.318 cm.) thick. It shall be equipped with devices for locating the position of the lid on the cup and the cup in the stove. A handle, attached permanently to the flange of the cup, is a desirable accessory.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

(*b*) *Lid.*—

1. Stirring Device.—The lid shall be equipped with a stirring device consisting of a vertical steel shaft, not less than 0.1 in. (0.254 cm.) nor more than 0.125 in. (0.318 cm.) in diameter, mounted in the center of the cup, and carrying two two-bladed brass propellers. The blades of both propellers shall be approximately 0.313 in. (0.795 cm.) wide and shall be set at an angle of approximately 45 deg. The smaller (upper) propeller shall have an over-all diameter of approximately 0.75 in. (1.905 cm.). The larger (lower) propeller shall have

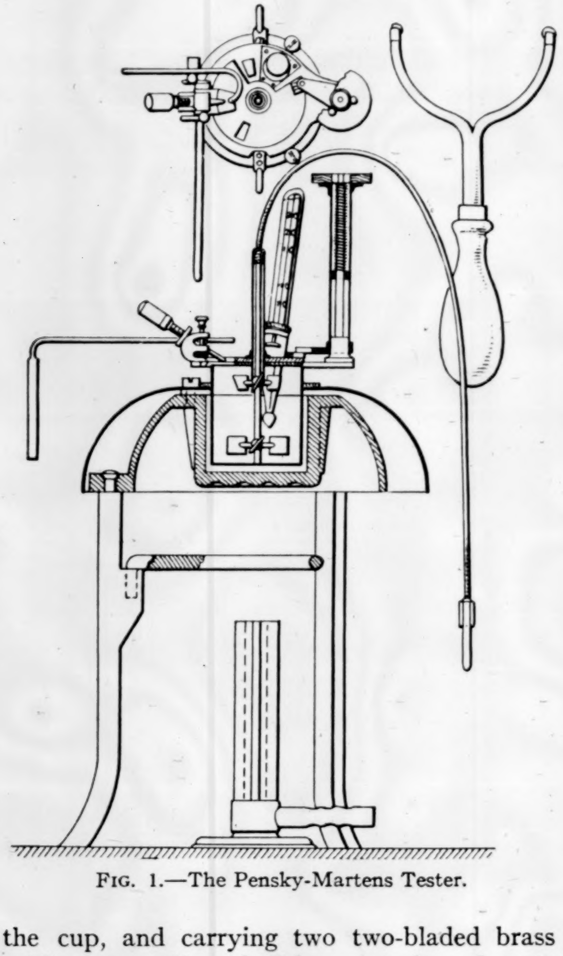
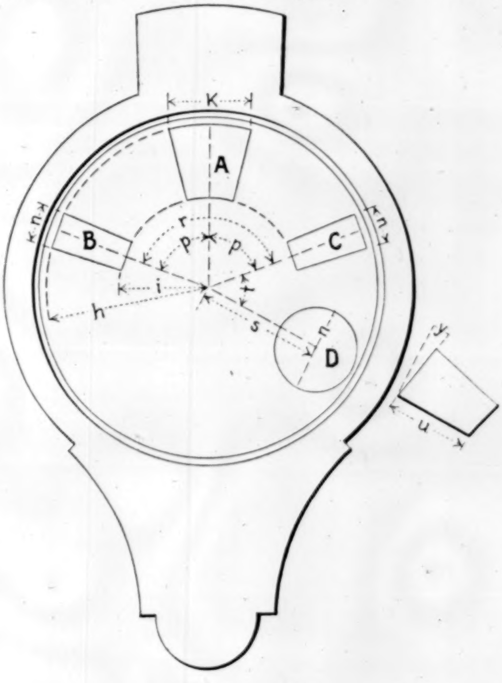


FIG. 1.—The Pensky-Martens Tester.

an over-all diameter between 1.25 and 1.75 in. (3.175 and 4.445 cm.). The thickness of the propeller blades shall be not less than 0.057 in. (0.145 cm.) nor more than 0.081 in. (0.206 cm.), which limits correspond respectively to No. 15 and No. 12 B. and S. gage sheet brass. The collars on which the propeller blades are mounted shall have horizontal and vertical dimensions not greater than 0.4 in. (1.016 cm.).



h Minimum 0.938 in., Maximum 0.969 in.
i " 0.531 ", " 0.563 "
k " 0.500 ", " 0.540 "
n " 0.187 ", " 0 219 "
s Approximately 0.75 in.
u " 0.5 ".
Angles p - Equal
Angle r - Min 135°; Max. 140°.
" t - " 50°; " 60°
" y - " 10°, " 15°

FIG. 2.—Cover for Pensky-Martens Tester.

The plane of the center of the upper propeller shall be 0.4 in. (1.016 cm.) below the level of the rim of the cup. The plane of the center of the lower propeller shall be 2.0 in. (5.08 cm.) below the level of the rim of the cup. The level of the rim of the cup is in effect the level of the plane part of the portion of the lower surface of the lid inside the rim.

2. Cover proper.—The cover proper shall be of brass and shall have a rim projecting downward almost to the flange of the cup and fitting the outside of the cup closely. The thickness of the cover, measured just inside the rim shall be not less than 0.031 in. (0.079 cm.) nor more than 0.078 in. (0.198 cm.). There shall be a proper locating device engaging with a corresponding locating device on the flange of the cup.

There shall be four openings in the cover, as indicated in Fig. 2.

Opening *A* is an area defined by arcs of two concentric circles and the intersected lengths of two radii. The radius of the outer circle shall be not less than 0.938 in. (2.383 cm.) nor more than 0.969 in. (2.461 cm.). The chord of the arc of the outer circle shall be not less than 0.500 in. (1.270 cm.) nor more than 0.540 in. (1.372 cm.).

Openings *B* and *C* are equal areas, each of the same general form as opening *A* but of approximately half the (angular) width. The radii of the defining inner and outer circles shall be within the limits specified for the radii of the two circles, arcs of which partially define opening *A*. The chord of the outer arc for opening *B* or opening *C* shall be not less than 0.187 in. (0.475 cm.) nor more than 0.219 in. (0.556 cm.). The sum of the areas of openings *B* and *C* shall be not less than 75 per cent nor more than 100 per cent of the area of opening *A*. Openings *B* and *C* shall be equally distant from opening *A* and radii drawn through each of their centers shall be at an angle of not less than 135 deg. nor more than 140 deg.

Openings *A*, *B*, and *C* need not conform exactly to the shape of geometrical figures bounded by arcs of two concentric circles and intersected lengths of radii. Their boundaries must, however, fall on or between the lines indicated by the limiting values of the dimensional specification of the preceding text and of Fig. 2.

Opening *D* is for a thermometer collar. Its center is approximately 0.75 in. (1.905 cm.) from the center of the lid and on a radius at an angle of not less than 50 deg. nor more than 60 deg. from a radius passing through the center of opening *C*. The thermometer collar shall have an inside diameter of approximately 0.5 in. (1.27 cm.). It shall be set at an angle of not less than 10 deg. nor more than 15 deg. from the perpendicular.

3. Shutter.—The lid shall be equipped with a brass shutter, approximately 0.094 in. (0.239 cm.) thick operating on the plane of the upper surface of the lid. The shutter shall be so shaped and mounted that it rotates on the axis of the horizontal center of the lid between two stops so placed that when in one extreme position the openings *A*, *B*, and *C* of the lid are completely closed and when in the other extreme position these orifices are completely opened.

4. Flame exposure device.—The flame exposure device shall have a tip with an opening 0.027 in. (0.069 cm.) to 0.031 in. (0.079 cm.) in diameter. The flame exposure device shall be equipped with an operating mechanism which, when the shutter is in the "open" position, depresses the tip so that the center of the orifice is between the planes of the under and upper surfaces of the lid proper at a point on a radius passing through the center of the larger opening *A* and approximately 0.1 in. (0.254 cm.) from the outer edge of the opening.

NOTE.

A pilot flame for automatic relighting of the exposure flame should be provided.

A bead 0.156 in. (0.396 cm.) in diameter, of some suitable material, may be mounted on the lid so that the size of the test flame can be regulated by comparison.

The mechanism operating the shutter should be of the spring type and constructed so that when at rest the shutter shall exactly close the three openings. When operated to the other extreme the three openings in the lid shall be exactly open and the tip of the exposure tube shall be fully depressed.

(*c*) *Stove.*—Heat shall be supplied to the cup by means of a properly designed stove which is equivalent to an air bath. This stove shall consist of (1) an air bath and (2) a top plate on which the flange of the cup rests.

1. Air bath.—The air bath shall have a cylindrical interior 1.625 in. (4.128 cm.) to 1.656 in. (4.206 cm.) deep and a diameter not less than 0.125 in. (0.317 cm.) nor more than 0.156 in. (0.396 cm.) greater than the outside diameter of the cup. The air bath may be either a flame heated metal casting or an electric resistance element.

NOTE.

If the heating element is a flame heated metal casting it shall be so designed and used that the temperature of bottom and walls is approximately the same. On this account it should be not less than 0.25 in. (0.635 cm.) thick. The casting shall be designed so that products of combustion of the flame cannot pass up and in contact with the cup.

If the air bath is of the electric resistance type it shall be constructed so that all parts of the interior surface are heated equally. This necessitates an even distribution of resistance wire over bottom and walls and a method of construction such that heat is given out from the whole core of the resistance element rather than directly from the wire.

2. Top plate.—The top plate shall be of metal. The total distance from the upper surface of the plate to the bottom of the air bath shall exceed the distance from the under surface of the flange to the bottom of the cup by not less than 0.063 in. (0.160 cm.) nor more than 0.125 in. (0.317 cm.).

The top plate shall be mounted with an air gap between it and the air bath. The top plate may be attached to the air bath by means of three screws and spacing bushings. The spacing bushings should be of proper thickness to define the air gap which shall be not less than 0.125 in. (0.317 cm.) nor more than 0.187 in. (0.475 cm.). The spacing bushings shall be not more than 0.375 in. (0.952 cm.) in diameter.

(*d*) *Thermometers.*—Two standard thermometers shall be used with the A.S.T.M. Pensky-Martens tester. The low range, "P. M. and Tag" thermometer shall be used for tests when the indicated reading falls within the limits 20 to 200° F. The "P.M. high" thermometer shall be used for tests when the indicated reading falls within the limits 230 to 700° F. For the range 200 to 230° F. either thermometer may be employed, depending on the convenience of the operator. The thermometers shall comply with the specifications given in Table I.

Thermometers shall be mounted so that the bottom of the bulb is 1.75 in. (4.445 cm.) below the level of the rim of the cup (which corresponds to the level of the lower surface of the portion of the lid inside the rim).

TABLE I.—SPECIFICATIONS FOR THERMOMETERS FOR PENSKY-MARTENS TESTER

	LOW RANGE "P.M. AND TAG."[1]	HIGH RANGE "P.M. HIGH."
Type	Etched stem glass.	Etched stem glass.
Total length	275 mm.	275 mm.
Stem	Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.	Plain front, enamel back, suitable thermometer tubing. Diameter 6 to 7 mm.
Bulb	Corning Normal, Jena 16 III, or equally suitable thermometric glass. Diameter less than stem, length 9 to 13 mm.	Corning Normal, Jena 16 III, or equally suitable thermometric glass. Diameter less than stem, length maximum 10 mm.
Actuating liquid	Mercury.	Mercury.
Range	20° F. to 230° F.	200° F. to 700° F.
Immersion	2¼ in. (57 mm.) from end of bulb. The words "2¼-in. immersion" etched on the stem, also a line around the stem to indicate depth of immersion.	2¼ in. (57 mm.) from end of bulb. The words "2¼-in. immersion" etched on the stem, also a line around the stem to indicate depth of immersion.

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[1] The low range "P.M. or Tag" thermometer is the same instrument as that specified for use with the Tag closed tester.

	LOW RANGE "P.M. AND TAG."[1]	HIGH RANGE "P.M. HIGH"
Distance from bottom of bulb	to 20° line, 75 to 90 mm.	to 200° line, 75 to 90 mm.
Distance from top of stem	to 230° line, 25 to 40 mm.	to 700° line, 25 to 40 mm.
Expansion chamber	Required.	None.
Filled	Nitrogen gas.	Nitrogen gas.
Top finish	Glass ring.	Glass ring.
Graduating	All lines, figures, and letters clear cut and distinct. Scale graduated in 1° divisions. Scale numbered every 10°, the first and each succeeding 5° line to be longer than the others.	All lines, figures, and letters clear cut and distinct. Scale graduated in 5° divisions. Scale numbered every 50°, the first and each succeeding 25° line to be longer than the others.
Special marking	"A.S.T.M. P.M. and Tag," serial number, manufacturer's name or trade mark etched on the stem.	"A.S.T.M., P.M., high," serial number, manufacturer's name or trade mark etched on the stem.
Accuracy	Error at any point in scale shall not exceed 1° F.	Error at any point in scale shall not exceed ½ smallest scale division.
Test for permanency		After being subjected to a temperature of 680° F. for 24 hours the accuracy shall be within the limit specified.
Points to be tested	32°, 100°, 150°, 212° F.	212°, 450°, 700° F.

PROCEDURE.

Procedure.

3. (*a*) All parts of the cup and its accessories shall be thoroughly clean and dry before starting the test. Particular care shall be taken to avoid the presence of any gasoline or naphtha used to clean the apparatus after a previous test.

(*b*) The cup shall be filled with the oil to be tested up to the level indicated by the filling mark.

(*c*) The lid shall be placed on the cup and the latter set in the stove. Care shall be taken to have the locating devices properly engaged. The thermometer shall be inserted. If it is known that the oil will flash above 220° F. the "P.M. high" thermometer may be selected; otherwise, it is preferable to start with the "P.M. and Tag" thermometer and change in case a temperature of 220 to 230° F. is reached.

(*d*) The test flame shall be lighted and adjusted so that it is of the size of a bead $\frac{5}{32}$ in. (3.97 mm.) in diameter.

(*e*) Heat shall be supplied at such a rate that the temperature read on the thermometer increases not less than 9 nor more than 11° F. per minute. The stirrer shall be turned at a rate of from 1 to 2 revolutions per second.

(*f*) Application of the test flame shall be made at each temperature reading which is a multiple of 2° F. up to 220° F. For the temperature range above 220° F., application shall be made at each temperature reading which is a multiple of 5° F. Application of the test flame shall be made by operating the device controlling the shutter and test flame burner so that the flame is lowered in one-half second, left in its lowered position for one second, and quickly raised to its high position. Stirring shall be discontinued during the application of the test flame.

Flash Point. 4. The flash point is taken as the temperature read on the thermometer at the time of the flame application that causes a distinct flash in the interior of the cup. The true flash must not be confused with the bluish halo that sometimes surrounds the test flame for the applications preceding the one that causes the actual flash.

Barometric Pressure. 5. The barometric pressure shall be observed and recorded. No corrections shall be made except in case of dispute when the flash point figure shall be corrected according to the following rule:

For each inch (25 mm.) below 29.92 in. (760 mm.) barometric reading add 1°.6 F. to the flash point.

For each inch (25 mm.) above 29.92 in. (760 mm.) barometric reading subtract 1°.6 F. from the flash point.

TENTATIVE METHOD OF TEST
FOR
SAPONIFICATION NUMBER.[1]

Serial Designation: D 94 – 21 T.

This method is issued under the fixed designation D 94; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

SOLUTIONS REQUIRED.

Alcoholic Solution for Saponification.—Dissolve 58 gr. of potassium hydrate "purified by alcohol" in 500 cc. of 95-per-cent purified ethyl alcohol. Allow the solution to settle in a dark place. Draw off the clear solution or filter through an asbestos filter and make up to one liter with 95-per-cent alcohol. The solution so prepared shall stand at least 20 hours before it is standardized.

Alcohol.—Purify 95-per-cent ethyl alcohol with silver oxide in the following manner:

Dissolve 1.5 g. of silver nitrate c.p. in about 3 cc. of water and add to 1 liter of alcohol in a glass stoppered bottle, and mix thoroughly. Dissolve 3 g. of potassium hydrate (by alcohol) in 10 to 15 cc. of warm alcohol. After cooling, add slowly to the alcoholic silver nitrate solution, stirring slightly. Allow the precipitated silver oxide to settle, siphon off the clear solution and distill on a steam bath.

Standard Hydrochloric Acid Solution.—One-half normal solution.

Phenolphthalein Solution.—One gram phenolphthalein in 100 cc. alcohol and water.

APPARATUS.

The saponification shall be carried out in a wide-mouthed flat-bottom extraction flask, or Erlenmeyer Flask, of 250 to 300-cc. capacity, fitted to a reliable condenser properly connected with a good cork. The boiling shall preferably be carried on by means of an electric hot plate.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

BLANK DETERMINATION.

Determination shall be made in duplicate in the alcoholic potash solution in the following manner:

Measure accurately into the flask 25 cc. of alcoholic potash solution from a calibrated pipette. The tip and outside of the pipette shall be wiped off with a clean filter paper before the solution is delivered. Then rinse out with 25 cc. of neutral alcohol. If a standard burette is used, allow 60 seconds total time for drawing and draining. Connect the flask to a suitable condenser and boil for three hours. Before disconnecting the flask, wash out the condenser with a few cubic centimeters of neutral alcohol; if a Soxhlet is used as the condenser the tip shall be washed off into the flask. Titrate while hot with N/2 HCl using three drops phenolphthalein indicator. The total number of cubic centimeters of N/2 HCl required for the blank represents the strength of the alcoholic potash solution.

PROCEDURE.

For straight fats or oils use 2 to 3 g. of the material, for oils containing over 30-per-cent of fatty oils use about 5 g. and for oils containing less than 30-per-cent of fatty oils use about 10 g.

Weigh the oil accurately, by difference, from a small beaker into the saponification flask. Add 25 cc. of alcoholic potash solution and 25 cc. of neutral alcohol in the same manner as for the blank, connect to the condenser and boil for three hours. Titrate while hot. Calculate the Saponification Number from the difference between the number of cubic centimeters of N/2 HCl required for the determination and the average of the two blanks, using the formula:

$$\text{Saponification Number} = \frac{\text{Difference, cubic centimeters} \times 28.05}{\text{Weight of oil, grams}}.$$

Petrolic ether may be used with compounded cylinder oils in the quantity of 50 cc. providing a Soxhlet extraction flask is used to periodically collect this petrolic ether. The Soxhlet flask should be so adjusted, through the addition of glass rodding or beads when necessary, so that it will just overflow with the full quantity of petrolic ether.

The percentage of fatty oil (or fat) in a compounded petroleum product can be calculated from the saponification number of such a product only when the saponification number of the fatty oil is known. If the saponification numbers of both fatty oil and compounded oil are known, the following formula should be used:

$$\text{Percentage of fatty oil} = \frac{100 \times \text{Saponification Number of compounded oil}}{\text{Saponification Number of fatty oil}}.$$

For this determination the following values of Saponification Number may be used:

FATTY OIL.	SAPONIFICATION NUMBER.
Lard oil	192–198
Tallow	193–198
Neatsfoot	193–204
Fish	140–193
Sperm	120–140
Castor	176–187
Rapeseed	170–179
Soya bean	189–197
Peanut	186–197
Cottonseed	191–197
Blown rapeseed	195–216
Blown cottonseed	210–225
Degras	110–210

TENTATIVE METHOD OF TEST
FOR
WATER IN PETROLEUM PRODUCTS.[1]

Serial Designation: D 95 - 21 T.

This method is issued under the fixed designation D 95; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. This method shall be used for crude petroleum, fuel oil and road oil, and may be used for any petroleum product.

SAMPLE.

Sample. 2. The sample shall be thoroughly representative of the material to be tested and the portion of the sample used for the test shall be thoroughly representative of the sample itself. Deviation from this rule shall not be permitted. The difficulties in obtaining proper representative samples for this determination are unusually great so that the importance of sampling cannot be too strongly emphasized.

APPARATUS.

Apparatus. 3. The preferred form shall be that of Dean and Stark[2] as shown in Fig. 1, and shall include the following:

(*a*) Distillation flask, 500-cc. capacity, of copper or well-annealed glass, round bottom.

(*b*) Reflux condenser, water cooled, glass-tube type.

(*c*) Special graduated distilling tube receiver of well-annealed glass graduated upward from 0 to 10 cc. in 0.1 cc. divisions, accurate to 0.05 cc.

(*d*) Gas burner or suitable electric heater.

Optional Form. 4. An optional form may be used and shall include the following:

(*a*) Distillation flask, 500-cc. capacity.

(*b*) Condenser, water cooled, glass-tube type, free from traps retarding complete draining.

(*c*) Receiver, of glass, capacity about 125 cc., A.S.T.M. water and sediment tube or equivalent. The A.S.T.M. water and sediment tube is shown in Fig. 2, and is graduated upward from 0 to 100 cc. as follows:

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

[2] *Journal of Industrial and Engineering Chemistry*, Vol. 12, p. 486 (1920).

RANGE.	SCALE DIVISIONS.	LIMIT OF ERROR.	NUMBERED.
0 - 3 cc.	0.1 cc.	0.05 cc.	1, 2, 3 cc.
3 - 5 "	0.5 "	0.2 "	4, 5 "
5 - 10 "	1.0 "	0.5 "	6, 8, 10 "
10 - 25 "	5.0 "	1.0 "	15, 20, 25 "
50 - 100 "	50.0 "	1.0 "	50, 100 "

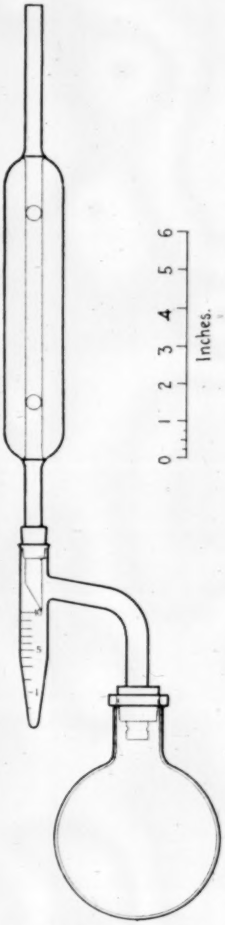

FIG. 1.—Water in Petroleum Products

(*d*) Gas burner or suitable electric heater.

(*e*) Thermometer, engraved-stem type, to indicate 400° F.

Diluent.

5. The diluent used in this method shall be gasoline, free from water. When subjected to distillation (A.S.T.M. Method D 86 - 21T) it shall show 5 per cent at a temperature not above 212° F. (100° C.) nor below 194° F. (90° C.). It shall show 90 per cent at a temperature not above 410° F. (205° C.).

PROCEDURE.

Measurement of Oil.

6. Exactly 100 cc. of the oil to be tested shall be measured in an accurate 100-cc. graduated cylinder at room temperature and poured into the distillation flask. The oil adhering to the walls of the 100-cc. graduated cylinder shall be transferred to the distillation flask by rinsing with two successive 50-cc. portions of gasoline, the cylinder being allowed to drain each time. The oil and gasoline in the distillation flask shall be thoroughly mixed by swirling the flask with proper care to avoid any loss of material. A boiling stone, such as a piece of unglazed porcelain, may be introduced for the purpose of preventing bumping during the subsequent distillation.

Assembly of Apparatus.

7. The apparatus shall be assembled in the following manner:

(*a*) If the preferred form of apparatus is used, the distillation flask shall be connected with the special graduated distilling tube receiver and this receiver with the reflux condenser by means of tight-fitting corks as shown in Fig. 1.

(*b*) If the optional form of apparatus is used, the vapor outlet tube of the distillation flask shall be inserted into the condenser, a tight connection being made by means of a cork. The receiver shall be supported in a suitable position at the other end of the condenser without the use of a cork or other connection. Proper precautions shall be taken to prevent the introduction into the receiver of water from any source other than the subsequent distillation process.

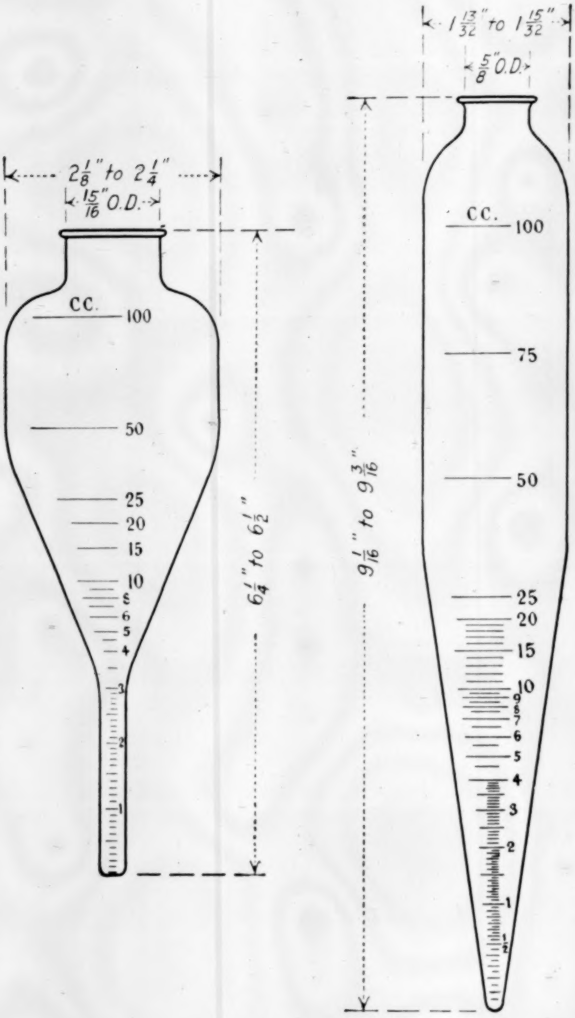
2 1/8" to 2 1/4"
15/16" O.D.
CC.
100
50
25
20
15
10
8
6
5
4
3
2
1
6 1/4" to 6 1/2"
1 13/32" to 1 15/32"
5/8" O.D.
9 1/16" to 9 3/16"
CC.
100
75
50
25
20
15
10
9
8
7
6
5
4
3
2
1
1/2

FIG. 2.

The mouth of the distillation flask shall be closed by a tight fitting cork supporting the thermometer in such a position that the top of the thermometer bulb is level with the bottom of the vapor outlet tube, where the latter is joined to the neck of the flask.

Application of Heat. 8. Either form of apparatus being assembled as prescribed, heat shall be applied to the distillation flask and shall be so regulated that the condensed distillate falls from the end of the condenser at the rate of 2 to 4 drops per second.

Distillation. 9. (*a*) With the preferred form of apparatus, distillation shall be continued at the specified rate until no water is visible on any part of the apparatus except at the bottom of the distilling tube receiver. This operation usually requires less than one hour. A persistent ring of condensed water in the condenser tube shall be removed by increasing the rate of distillation for a few minutes.

(*b*) With the optional form of apparatus, distillation shall be continued at the specified rate until the thermometer indicates a vapor temperature of 400° F. and until all condensed water has disappeared from the walls of the distillation flask and of the condenser.

Recording. 10. With either form of apparatus, the volume of condensed water, measured in the graduated receiver at room temperature, shall be recorded as "— per cent Water, A.S.T.M. Method."

ACCURACY.

Accuracy. 11. With proper care and attention to details, duplicate determinations of water by this method shall not differ from each other by more than 0.2 cc. of water provided the graduated receiver is accurate and readable to this degree.

NOTE.—When the sample to be tested contains more than 10 per cent of water, the volume of material used shall be decreased to that which will yield somewhat less than 10 cc. of water. Otherwise the procedure shall be conducted as prescribed.

TENTATIVE METHOD OF TEST
FOR
WATER AND SEDIMENT IN PETROLEUM PRODUCTS, BY MEANS OF CENTRIFUGE.[1]

Serial Designation: D 96 - 21 T.

This method is issued under the fixed designation D 96; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. This method may be used for crude mineral oils and fuel oils. A centrifuge method for "Water and Sediment" is not entirely satisfactory because the amount of water obtained is nearly always lower than the actual water content. Nevertheless, on account of the wide use of the centrifuge for this purpose, it is desirable that the method of making the determination be standardized as far as possible. It must be clearly understood that the reading of the centrifuge tube includes both the sediment and the precipitated water. Accurate determination of water content if desired, should be made in accordance with the Tentative Method of Test for Water in Petroleum Products (D 95 - 21 T) of the American Society for Testing Materials.[2]

Sample. 2. The sample shall be thoroughly representative of the material in question and the portion used for the test shall be thoroughly representative of the sample itself. Deviation from this rule shall not be permitted. The difficulties in obtaining proper representative samples for this determination are unusually great so that the importance of sampling cannot be too strongly emphasized.

APPARATUS.

Centrifuge. 3. The centrifuge shall be capable of whirling at the required speed at least two 100-cc. centrifuge tubes filled with water. It shall be of sound design and rugged construction so that it may be operated without danger. The tube carriers shall be so designed that the glass centrifuge tubes may be cushioned with water, rubber or other suitable material. The tube holders shall be surrounded during the operation by a suitable metal shield or case, strong enough to eliminate danger if any breakage occurs.

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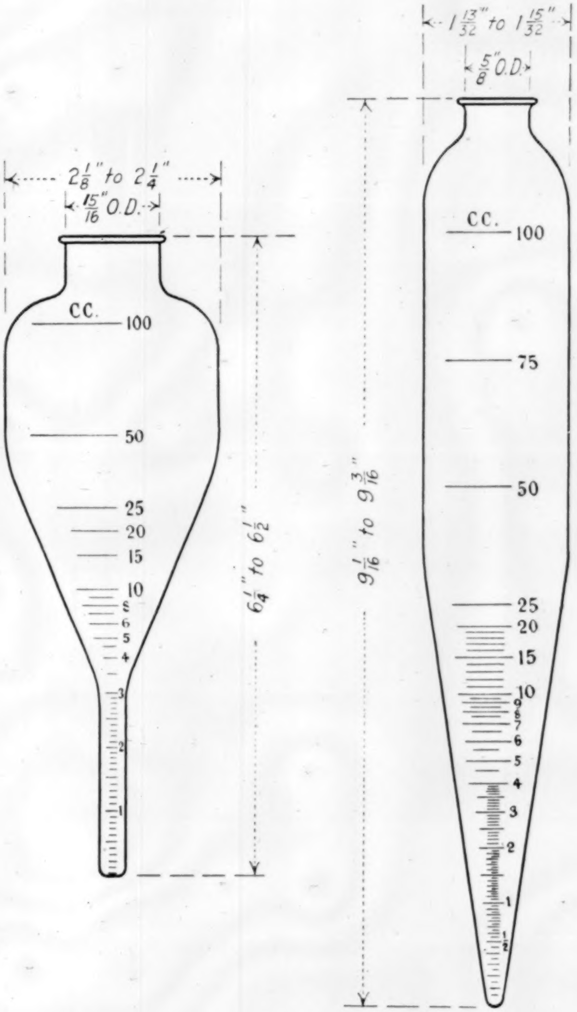
[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

[2] See page 666.

The preferred form of centrifuge shall have a diameter of swing (tip to tip of whirling tubes) of 15 to 17 in. and a speed of at least



$2\frac{1}{8}$" to $2\frac{1}{4}$"
$\frac{15}{16}$" O.D.
CC.
100
50
25
20
15
10
8
6
5
4
3
2
1
$6\frac{1}{4}$" to $6\frac{1}{2}$"
$1\frac{13}{32}$" to $1\frac{15}{32}$"
$\frac{5}{8}$" O.D.
CC.
100
75
50
25
20
15
10
9
8
7
6
5
4
3
2
1
$\frac{1}{2}$
$9\frac{1}{16}$" to $9\frac{3}{16}$"

FIG. 1.

1500 r.p.m. or the equivalent. If the available centrifuge has a diameter of swing varying from these limits, it shall be run at the proper speed to give the same centrifugal force at the tips of the tubes as that obtained with the preferred form of centrifuge. The proper speed shall be calculated from the following formula in which *d* represents diameter of swing (tip to tip of whirling tubes) of the centrifuge used:

$$\text{R.p.m.} = 1500\sqrt{\frac{16}{d}}$$

Centrifuge Tubes. 4. The centrifuge tubes, A.S.T.M. type, shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 cc. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube as follows:

RANGE.	SCALE DIVISIONS.	LIMIT OF ERROR.	NUMBERED.
0 – 3 cc.	0.1 cc.	0.05 cc.	1, 2, 3 cc.
3 – 5 "	0.5 "	0.2 "	4, 5 "
5 – 10 "	1.0 "	0.5 "	6, 8, 10 "
10 – 25 "	5.0 "	1.0 "	15, 20, 25 "
50 – 100 "	50.0 "	1.0 "	50, 100 "

The shape is optional provided it does not conflict with the other requirements. Satisfactory types are shown in Fig. 1.

Bath. 5. The water or oil bath shall be of sufficient depth for immersing the centrifuge tubes in a vertical position to the 100-cc. mark. Means shall be provided for heating this bath to 100° F.

PROCEDURE.

Procedure. 6. (*a*) Exactly 50 cc. of 90-per-cent benzol shall be measured into each of two centrifuge tubes and exactly 50 cc. of the oil to be tested shall then be added to each. The centrifuge tubes shall be tightly stoppered and shall be shaken vigorously until the contents are thoroughly mixed. The temperature of the bath shall be maintained at 100° F. and the centrifuge tubes shall be immersed therein to the 100-cc. mark for 10 minutes.

(*b*) The two centrifuge tubes shall then be placed in the centrifuge on opposite sides and shall be whirled at a rate of 1400 to 1500 r.p.m. or the equivalent for 10 minutes. The combined volume of water and sediment at the bottom of each tube shall be read and recorded, estimating to 0.1 cc. if necessary. The centrifuge tubes shall then be replaced in the centrifuge, again whirled for 10 minutes as before and removed for reading the volume of water and sediment as before. This operation shall be repeated until the combined volume of water and sediment in each tube remains constant for three consecutive readings. In general, not more than four whirlings will be required.

7. The combined total volume of water and sediment shall be read on each tube, estimating to 0.1 cc. if necessary. The sum of the two readings shall be recorded as percentage of water and sediment, centrifuge method. **Water and Sediment.**

ACCURACY.

8. With care and proper attention to details, duplicate determinations of water and sediment by this method should not differ by more than 0.2 cc. provided the centrifuge tubes are accurate and readable to this degree. **Accuracy.**

TENTATIVE METHOD OF TEST
FOR
CLOUD AND POUR POINTS OF PETROLEUM PRODUCTS.[1]

Serial Designation: D 97 – 21 T.

This method is issued under the fixed designation D 97 ; the final number indicates the year of original issue, or in case of revision, the year of last revision.

Issued, 1921.

Definitions. 1. (*a*) The Cloud Point of a petroleum oil is that temperature at which paraffin wax or other solid substances begin to crystallize out or separate from solution when the oil is chilled under certain definite specified conditions.

(*b*) The Pour Point of a petroleum oil is the lowest temperature at which this oil will pour or flow when it is chilled without disturbance under certain definite specified conditions.

Scope. 2. (*a*) The test for cloud point shall be used only for oils which are transparent in layers $1\frac{1}{2}$ in. thick.

(*b*) The test for pour point shall be used for all other petroleum oils and may be used for oils on which the test for cloud point is permitted.

APPARATUS.

(See Fig. 1.)

Test Jar. 3. The test jar, *a*, shall be of clear glass, cylindrical form, flat bottom, approximately $1\frac{1}{4}$ in. in inside diameter and $4\frac{1}{2}$ to 5 in. high. An ordinary 4-oz. oil sample bottle may be used if the test jar is not available.

Thermometer. 4. The thermometer, *b*, shall conform to the following specifications.

Type: Etched stem glass.
Total length: 222 mm.
Stem: Plain front, enamel back, suitable thermometer tubing; diameter 7 to 8 mm.
Bulb: Corning Normal. Jena 16 III, or equally suitable thermometric glass; maximum length, 9.5 mm.; diameter, not greater than stem.
Actuating liquid: Mercury.
Range: −36° to +120° F.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. K. G. Mackenzie, Secretary of Committee D-2 on Petroleum Products and Lubricants, 17 Battery Place, New York City.

Immersion: 4¼ in. The words "4¼-in. immersion" etched on the stem and also a line around the stem to indicate the depth of immersion.
Distance to −36° line from bottom of bulb: 120 to 130 mm.
Distance to 120° line from top of stem: 19 to 25 mm.
Expansion chamber: To hold 212° F.
Filled: Nitrogen gas.
Top finish: Plain.
Graduation: All lines, figures and letters clear cut and distinct.
Scale graduated in 2° F. divisions.
Scale numbered every 20° F. starting at −20° F. The −30° line and each succeeding 10° line to be longer than the others.
Special markings: "A.S.T.M. Cloud and Pour," serial number and manufacturer's name or trade mark etched on the stem.
Accuracy: Error at any point on scale shall not exceed one smallest scale division.
Points to be tested for certification: −28°, +32°, +92° F.

Cork. 5. The cork, *c*, shall fit the test jar, and shall be bored centrally to take the test thermometer.

Jacket. 6. The jacket, *d*, shall be of glass or metal, shall be water tight, of cylindrical form, flat bottom, about 4½ in. deep, with inside diameter ½ in. greater than outside diameter of the test jar.

Cork Disk. 7. A disk of cork or felt, *e*, ¼ in. thick and of the same diameter as the inside of the jacket will be required.

Gasket. 8. The ring gasket, *f*, shall be about 3/16 in. thick, and made to fit snugly around the outside of the test jar and loosely inside the jacket. This gasket may be made of cork, felt or other suitable material, elastic enough to cling to the test jar and hard enough to hold its shape. The purpose of the ring gasket is to prevent the test jar from touching the jacket.

Bath. 9. The cooling bath, *g*, shall be of a type suitable for obtaining the required temperatures. The size and shape of the bath are optional but a support, suitable for holding the jacket firmly in a vertical position, is essential. The required bath temperatures may be maintained by refrigeration if available, otherwise by suitable freezing mixtures.

NOTE.—The freezing mixtures commonly used are as follows:

For temperatures down to 35° F., ice and water.
" " " " −5° F., crushed ice and sodium chloride.
" " " " −25° F., crushed ice and calcium chloride.
" " " " −70° F., solid carbon dioxide and acetone.

The last named mixture may be made as follows: In a covered metal beaker chill a suitable amount of acetone to 10° F., or lower, by means of an ice-salt mixture. Invert a cylinder of liquid carbon dioxide and draw off carefully into a chamois skin bag the desired amount of carbon dioxide, which through rapid evaporation will quickly become solid. Then add to the chilled acetone enough of the solid carbon dioxide to give the desired temperature.

PROCEDURE.

Procedure for Cloud Point.

10. The oil to be tested shall be brought to a temperature at least 25° F. above the approximate cloud point. Moisture, if present, shall be removed by any suitable method, as by filtration through dry filter paper until the oil is perfectly clear but such filtration shall be made at a temperature at least 25° F. above the approximate cloud point.

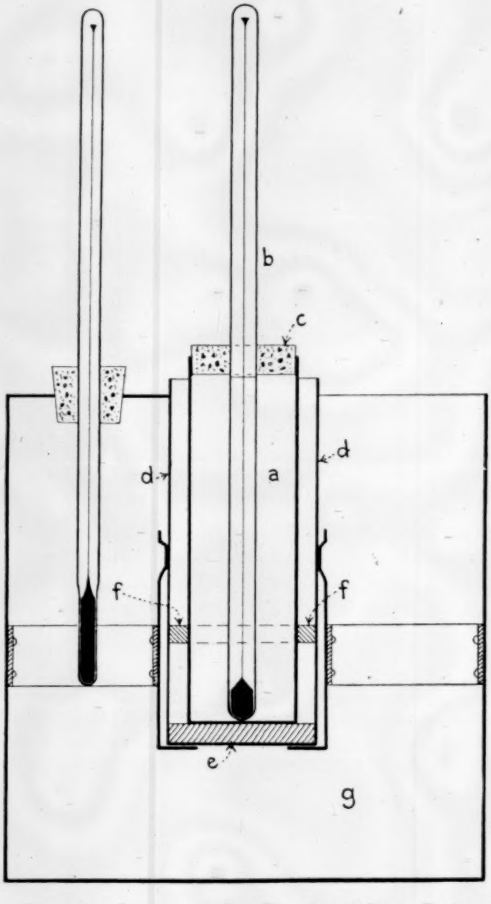

FIG. 1.—Apparatus for Cloud and Pour Test (as assembled for Cloud Test).

The clear oil shall be poured into the test jar, *a*, to a height of not less than 1 nor more than $1\frac{1}{4}$ in. The test jar may be marked to indicate the proper level.

The test jar shall be tightly closed by the cork, *c*, carrying the test thermometer, *b*, in a vertical position in the center of the jar with the thermometer bulb resting on the bottom of the jar.

The disk, *e*, shall be placed in the bottom of the jacket, *d*, and the test jar with the ring gasket, *f*, 1 in. above the bottom shall be inserted into the jacket. The disk, jacket and inside of jacket shall be clean and dry.

The temperature of the cooling bath, *g*, shall be adjusted so that it is below the cloud point of the oil by not less than 15 nor more than 30° F. and this temperature shall be maintained throughout the test. The jacket, containing the test jar, shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

At each test thermometer reading which is a multiple of 2° F. the test jar shall be removed from the jacket, quickly but without disturbing the oil, inspected for cloud and replaced in the jacket. This complete operation shall require not more than three seconds.

When the bottom of the oil has become opaque to a height of not less than $\frac{1}{8}$ not more than $\frac{3}{16}$ in., the reading of the test thermometer, corrected for error if necessary, shall be recorded as the cloud point. The required height of cloud is approximately at the middle of the thermometer bulb. The test jar may be marked to indicate the proper level.

Procedure for Pour Point.

11. Oils having a viscosity greater than 600 seconds, Saybolt Universal at 100° F., shall be allowed to stand in the test jar at a temperature of 60 to 85° F. for at least five hours prior to making the test for pour point. A viscous oil which has been stored in a warm place is liable to show an abnormally low, fictitious pour point unless this precaution is observed. Oils having a viscosity not greater than 600 seconds, Saybolt Universal at 100° F., may be tested without such preliminary standing.

After preliminary standing, if necessary, the oil to be tested shall be brought to a temperature of 90° F., or to a temperature 15° F. higher than its pour point, if this pour point is above 75° F., and shall be poured into the test jar, *a*, to a height of not less than 2 nor more than $2\frac{1}{4}$ in. The jar may be marked to indicate the proper level.

The test jar shall be tightly closed by the cork, *c*, carrying the test thermometer, *b*, in a vertical position in the center of the jar with the thermometer bulb immersed so that the beginning of the capillary shall be $\frac{1}{8}$ in. below the surface of the oil.

The disk, *e*, shall be placed in the bottom of the jacket, *d*, and the test jar, with the ring gasket, *f*, 1 in. above the bottom, shall be inserted into the jacket. The disk, gasket and inside of jacket shall be clean and dry.

The temperature of the cooling bath, *g*, shall be adjusted so that it is below the pour point of the oil by not less than 15 nor more than 30° F. and this temperature shall be maintained throughout the test. The jacket, containing the test jar, shall be supported firmly in a vertical position in the cooling bath so that not more than 1 in. of the jacket projects out of the cooling medium.

At each test thermometer reading which is a multiple of 5° F., the test jar shall be removed from the jacket carefully and shall be tilted just sufficiently to ascertain whether the oil around the thermometer remains liquid. As long as the oil around the thermometer flows when the jar is tilted slightly, the test jar shall be replaced in the jacket. The complete operation of removal and replacement shall require not more than three seconds. As soon as the oil around the thermometer does not flow when the jar is tilted slightly, the test jar shall be held in a horizontal position for exactly five seconds, and observed carefully. If the oil around the thermometer shows any movement under these conditions, the test jar shall be immediately replaced in the jacket and the same procedure shall be repeated at the next temperature reading 5° F. lower. As soon as a temperature is reached at which the oil around the thermometer shows no movement when the test jar is held in a horizontal position for exactly five seconds, the test shall be stopped.

The lowest reading of the test thermometer, corrected for error if necessary, at which the oil around the thermometer shows any movement when the test jar is held in a horizontal position for exactly five seconds, shall be recorded as the pour point.

TENTATIVE SPECIFICATIONS
FOR
CALCIUM CHLORIDE FOR DUST PREVENTION.[1]

Serial Designation: D 98 - 21 T.

These specifications are issued under the fixed designation D 98; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover calcium chloride to be applied to the surface of highways as a dust preventive.

I. PROPERTIES AND TESTS.

Physical Properties. 2. The calcium chloride shall be in the form of loose dry lumps or flakes free from dust, and fine enough to feed readily through the common forms of spreaders used in road work.

Chemical Composition. 3. Ten grams of the material dissolved in 100 cc. of boiling water shall show less than 1.0 per cent insoluble residue. Not more than 0.5 cc. of normal acid shall be required to neutralize the alkalinity of the filtrate. The percentage of calcium chloride shall be not less than 70 per cent of the material tested. The percentage of calcium chloride shall be calculated from the percentage of calcium in the filtrate above referred to, after making a deduction for the SO_4, which shall be assumed to be in combination as $CaSO_4$.

II. PACKAGES.

Packages. 4. The calcium chloride shall be delivered in tight steel drums about 21 in. in diameter and 32 to 34 in. in height. The name of the manufacturer, the lot number, the percentage of calcium chloride guaranteed by the manufacturer and the net weight of contents, shall be plainly marked on each drum.

III. INSPECTION.

Inspection. 5. Every facility for inspection shall be provided the purchaser at the plant. The manufacturer shall take and retain a sealed sample of each car lot of calcium chloride and shall deliver same to the purchaser, provided the purchaser does not elect to have his own representative present at the plant when the car is sampled.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

Rejection. 6. Calcium chloride shall be rejected if it fails to pass any of these specifications and if it cakes or becomes sticky in the drums.

IV. BASIS OF PAYMENT.

Basis of Payment. 7. Payment will be made on the basis of total number of pounds of 100-per-cent calcium chloride delivered.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT, 40 TO 50 PENETRATION.[1]

Serial Designation: D 99 – 21 T.

These specifications are issued under the fixed designation D 99; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope.

1. These specifications cover a grade of asphalt cement suitable for use in the construction of sheet asphalt and asphaltic concrete pavements in various climates or in similar pavements in cold climates when subjected to heavy traffic.

Properties.

2. The asphalt cement shall be homogeneous and free from water. It shall meet the following requirements:

(*a*) Penetration at 25° C. (77° F.), 100 g., 5 sec. . . . . 40 to 50

(*b*) Flash point (open cup) . . . . not less than 175° C. (347° F.)

(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr. . . . . not more than 2 per cent

(*d*) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating. . . . . not less than 60 per cent.

(*e*) Ductility at 25° C. (77° F.) . . . . not less than 30 cm.

(*f*) Bitumen soluble in carbon disulfide. . . not less than 65 per cent

Methods of Testing.

3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Tentative Method of Test for Flash and Fire Points by Means of Open-Cup (Serial Designation: D 92 – 21 T);[3]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 – 21 T);[4]

(*e*) *Bitumen Soluble in Carbon Disulfide:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1921 Book of A.S.T.M. Standards. [3] See p. 651. [4] See p. 704.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT, 50 TO 60 PENETRATION.[1]

Serial Designation: D 100 – 21 T.

These specifications are issued under the fixed designation D 100; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. These specifications cover a grade of asphalt cement suitable for use in the construction of sheet asphalt and asphaltic concrete pavements in any climate under moderate and light traffic. Its use, however, in hot climates should depend upon the character of the aggregate.

Properties. 2. The asphalt cement shall be homogeneous and free from water. It shall meet the following requirements:

(*a*) Penetration at 25° C. (77° F.), 100 g., 5 sec. . . . . . 50 to 60

(*b*) Flash point (open cup) . . . . not less than 175° C. (347° F.)

(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr. . . . . . not more than 2 per cent

(*d*) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating, ... not less than 60 per cent

(*e*) Ductility at 25° C. (77° F.) . . . . not less than 30 cm.

(*f*) Bitumen soluble in carbon disulfide . . . . not less than 65 per cent

Methods of Testing. 3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Tentative Method of Test for Flash and Fire Points by Means of Open-Cup (Serial Designation: D 92 – 21 T);[3]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 – 21 T);[4]

(*e*) *Bitumen Soluble in Carbon Disulfide:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1921 Book of A.S.T.M. Standards. [3] See p. 651. [4] See p. 704.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT, 60 TO 70 PENETRATION.[1]

Serial Designation: D 101 - 21 T.

These specifications are issued under the fixed designation D 101; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Scope. 1. These specifications cover a grade of asphalt cement suitable for use in sheet asphalt and asphaltic concrete pavements under medium and light traffic in cold climates and for asphalt macadam penetration work in warm climates.

Properties. 2. The asphalt cement shall be homogeneous and free from water. It shall meet the following requirements:

(*a*) Penetration at 25° C. (77° F.), 100 g., 5 sec.......60 to 70
(*b*) Flash point (open cup)........not less than 175° C. (347° F.)
(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr.. not more than 2 per cent
(*d*) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating..................not less than 60 per cent
(*e*) Ductility at 25° C. (77° F.).............not less than 40 cm.
(*f*) Bitumen soluble in carbon disulfide...not less than 68 per cent

Methods of Testing. 3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Tentative Method of Test for Flash and Fire Points by Means of Open-Cup (Serial Designation: D 92 - 21 T);[3]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 21 T;)[4]

(*e*) *Bitumen Soluble in Carbon Disulfide:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1921 Book of A.S.T.M. Standards. [3] See p. 651. [4] See p. 704.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT, 70 TO 90 PENETRATION.[1]

Serial Designation: D 102 - 21 T.

These specifications are issued under the fixed designation D 102; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. These specifications cover a grade of asphalt cement suitable for asphalt macadam penetration work in temperate and warm climates.

Properties. 2. The asphalt cement shall be homogeneous and free from water. It shall meet the following requirements:

(*a*) Penetration at 25° C. (77° F), 100 g., 5 sec........70 to 90

(*b*) Flash point (open cup).......not less than 175° C. (347° F.)

(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr... not more than 2 per cent

(*d*) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating.....................not less than 60 per cent

(*e*) Ductility at 25° C. (77° F.).............not less than 40 cm.

(*f*) Bitumen soluble in carbon disulfide...not less than 68 per cent

Methods of Testing. 3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Tentative Method of Test for Flash and Fire Points by Means of Open-Cup (Serial Designation: D 92 - 21 T);[3]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 21 T);[4]

(*e*) *Bitumen Soluble in Carbon Disulfide:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1921 Book of A.S.T.M. Standards. [3] See p. 651. [4] See p. 704.

TENTATIVE SPECIFICATIONS
FOR
ASPHALT CEMENT, 90 TO 120 PENETRATION.[1]

Serial Designation: D 103 - 21 T.

These specifications are issued under the fixed designation D 103; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope.

1. These specifications cover a grade of asphalt cement suitable for asphalt macadam penetration work in temperate and cold climates.

Properties.

2. The asphalt cement shall be homogeneous and free from water. It shall meet the following requirements:

(*a*) Penetration at 25° C. (77° F.), 100 g., 5 sec......90 to 120

(*b*) Flash point (open-cup)........not less than 175° C. (347° F.)

(*c*) Loss on heating at 163° C. (325° F.), 50 g., 5 hr......
not more than 2 per cent

(*d*) Penetration at 25° C. (77° F.), 100 g., 5 sec., of residue after heating at 163° C. (325° F.) as compared with penetration of asphalt cement before heating..................not less than 60 per cent

(*e*) Ductility at 25° C. (77° F.).............not less than 40 cm.

(*f*) Bitumen soluble in carbon disulfide...not less than 70 per cent

Methods of Testing.

3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Penetration:* Standard Method of Test for Penetration of Bituminous Materials (Serial Designation: D 5);[2]

(*b*) *Flash Point:* Tentative Method of Test for Flash and Fire Points by Means of Open-Cup (Serial Designation: D 92 - 21 T);[3]

(*c*) *Loss on Heating:* Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (Serial Designation: D 6);[2]

(*d*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 21 T);[4]

(*e*) *Bitumen Soluble in Carbon Disulfide:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4);[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] 1921 Book of A.S.T.M. Standards. [3] See p. 651. [4] See p. 704.

TENTATIVE SPECIFICATIONS
FOR
HIGH-CARBON TAR FOR SURFACE TREATMENT, COLD APPLICATION.[1]

Serial Designation: D 104 – 21 T.

These specifications are issued under the fixed designation D 104; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Properties. 1. The tar shall meet the following requirements:

(*a*) Water........................not more than 2.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.) ....1.14 to 1.18

(*c*) Specific viscosity, Engler,[2] 50 cc. at 40° C. (104° F.)....8 to 20

(*d*) Distillation test on water-free material:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)..................not more than 7.00 per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)..................not more than 18.00 "
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)..................not more than 28.00 "
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)..................not more than 35.00 "
Residue, by weight ....not less than 65.00 "

(*e*) Specific gravity at 25°/25° C. (77°/77° F.) of total distillate to 300° C. (572° F.) ....not less than 1.01

(*f*) Softening point (Cube-in-Water Method) of residue from distillation test...................not more than 60° C. (140° F.)

(*g*) Free carbon........................4.00 to 12.00 per cent

Methods of Testing. 2. The properties enumerated in these specifications shall unless otherwise indicated be determined in accordance with the following methods of test of the American Society for Testing Materials:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] Within the viscosity limits designated a material should be chosen to meet the local conditions of temperature, road conditions and climate. It is recommended that a permissible range of 5 be given and that materials be called for under the following headings: Light 8–13, Medium 11–16, Heavy 15–20.

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Specific Viscosity:*[3] Method contained in *Bulletin No. 691*, U. S. Department of Agriculture, the instrument being standardized by the Bureau of Standards. The results shall be reported as specific viscosity compared with water at 25° C. (77° F.).

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[4]

(*e*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[4]

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[4]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] The Engler test has not been standardized by the American Society for Testing Materials Committees of the Society have under consideration the Saybolt Furol Apparatus, which may be adopted later.

[4] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
LOW-CARBON TAR FOR SURFACE TREATMENT, COLD APPLICATION.[1]

Serial Designation: D 105 - 21 T.

These specifications are issued under the fixed designation D 105; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Properties. 1. The tar shall meet the following requirements:

(*a*) Water........................not more than 2.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.)......1.10 to 1.14

(*c*) Specific viscosity, Engler,[2] 50 cc. at 40°C. (104° F.)..20 to 35

(*d*) Distillation test on water-free material:

Total Distillate, by weight, 0 to 170° C.
(32 to 338° F.)..................not more than 2.00 per cent
Total Distillate, by weight, 0 to 235° C.
(32 to 455° F.)..................not more than 15.00 "
Total Distillate, by weight, 0 to 270° C.
(32 to 518° F.)..................not more than 30.00 "
Total Distillate, by weight, 0 to 300° C.
(32 to 572° F.)..................not more than 40.00 "
Residue, by weight..................not less than 60.00 "

(*e*) Softening point (Cube-in-Water Method) of residue from distillation test........................not more than 70° C. (158° F.)

(*f*) Free carbon..................not more than 5.00 per cent

Methods of Testing. 2. The properties enumerated in these specifications shall unless otherwise indicated be determined in accordance with the following methods of test of the American Society for Testing Materials:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] Within the viscosity limits designated a material should be chosen to meet the local conditions of temperature, road conditions and climate. It is recommended that a permissible range of 5 be given and that materials be called for under the following headings: Light 20–25, Medium 25–30, Heavy 30–35.

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements, and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Specific Viscosity:*[3] Method contained in *Bulletin No. 691*, U. S. Department of Agriculture, the instrument being standardized by the Bureau of Standards. The results shall be reported as specific viscosity compared with water at 25° C. (77° F.).

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[4]

(*e*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[4]

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[4]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] The Engler test has not been standardized by the American Society for Testing Materials. Committees of the Society have under consideration the Saybolt Furol apparatus, which may be adopted later.

[4] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS

FOR

HIGH-CARBON TAR CEMENT FOR USE COLD IN REPAIR WORK (CUT-OUT PRODUCT).[1]

Serial Designation: D 106 – 21 T.

These specifications are issued under the fixed designation D 106; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Properties. 1. The tar cement shall meet the following requirements:

(*a*) Water..........................not more than 2.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.).......1.15 to 1.20

(*c*) Specific viscosity, Engler, 50 cc. at 40° C. (104° F.)..40 to 70

(*d*) Distillation test on water-free material:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)	4.00 to 12.00 per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)	8.00 to 20.00 "
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)	18.00 to 30.00 "
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)	not more than 35.00 "
Residue, by weight	not less than 65.00 "

(*e*) Softening point (Cube-in-Water Method) of residue from distillation test........................not more than 75 C. (167° F.)

(*f*) Free carbon........................12.00 to 22.00 per cent

Methods of Testing. 2. The properties enumerated in these specifications shall unless otherwise indicated be determined in accordance with the following methods of test of the American Society for Testing Materials:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Specific Viscosity:*[3] Method contained in *Bulletin No. 691*, U. S. Department of Agriculture, the instrument being standardized by the Bureau of Standards. The results shall be reported as specific viscosity compared with water at 25° C. (77° F.).

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[4]

(*e*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[4]

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[4]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] The Engler test has not been standardized by the American Society for Testing Materials. Committees of the Society have under consideration the Saybolt Furol apparatus, which may be adopted later.

[4] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
LOW-CARBON TAR CEMENT FOR USE COLD IN REPAIR WORK (CUT-BACK PRODUCT).[1]

Serial Designation: D 107 - 21 T.

These specifications are issued under the fixed designation D 107; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Properties.

1. The tar cement shall meet the following requirements:

(*a*) Water........................not more than 2.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.)... 1.09 to 1.15

(*c*) Specific viscosity, Engler, 50 cc. at 40° C. (104° F.)..35 to 45

(*d*) Distillation test on water-free material:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)	not more than 3.00 per cent.
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)	not more than 20.00 "
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)	not more than 30.00 "
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)	not more than 40.00 "
Residue, by weight	not less than 60.00 "

(*e*) Softening point (Cube-in-Water Method) of residue from distillation test.....................not more than 75° C. (167° F.)

(*f*) Free carbon ....not more than 5.00 per cent

Methods of Testing.

2. The properties enumerated in these specifications shall unless otherwise indicated be determined in accordance with the following methods of test of the American Society for Testing Materials:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Specific Viscosity:*[3] Method contained in *Bulletin No. 691*, U. S. Department of Agriculture, the instrument being standardized by the Bureau of Standards. The results shall be reported as specific viscosity compared with water at 25° C. (77° F.).

(*d*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[4]

(*e*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[4]

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[4]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] The Engler test has not been standardized by the American Society for Testing Materials. Committees of the Society have under consideration the Saybolt Furol apparatus, which may be adopted later.

[4] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS

FOR

HIGH-CARBON TAR FOR SURFACE TREATMENT, HOT APPLICATION.[1]

Serial Designation: D 108 – 21 T.

These specifications are issued under the fixed designation D 108; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Properties. 1. The tar shall meet the following requirements:

(*a*) Water.................................... 0.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.).. 1.20 to 1.26

(*c*) Float test at 32° C. (89°.6 F.).............. 60 to 150 sec.

(*d*) Distillation test:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)..................not more than 0.00 per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)..................not more than 10.00 "
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)..................not more than 15.00 "
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)..................not more than 25.00 "
Residue, by weight.................. not less than 75.00 "

(*e*) Specific gravity at 25° C. (77° F.) of total distillate to 300° C. (572° F.) ....not less than 1.03

(*f*) Softening point (Cube-in-Water Method) of residue from distillation test......................not more than 75° C. (167° F.)

(*g*) Free carbon ....12.00 to 22.00 per cent

Methods of Testing. 2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials. 25 W. Forty-third St., New York City.

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[3]

(*d*) *Softening Point:* Standard Method of Tests for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[3]

(*e*) *Float Test:* Standard Method of Sampling and Analysis of Creosote Oil (Serial Designation: D 38)[3] (Sections 17 and 18);

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[3]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
LOW-CARBON TAR FOR SURFACE TREATMENT, HOT APPLICATION.

Serial Designation: D 109 - 21 T.

These specifications are issued under the fixed designation D 109; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Properties. 1. The tar shall meet the following requirements:

(*a*) Water.......................................0.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.)...... 1.14 to 1.18

(*c*) Float test at 32° C. (89°.6 F.)................60 to 150 sec.

(*d*) Distillation test:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)		0.00 per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)	not more than	4.00 "
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)	not more than	13.00 "
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)	not more than	26.00 "
Residue, by weight	not less than	74.00 "

(*e*) Softening point (Cube-in-Water Method) of residue from distillation test ....not more than 75° C. (167° F.)

(*f*) Free carbon ....not more than 5.00 per cent

Methods of Testing. 2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[2]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third Street, New York City.

[2] See p. 706.

[3] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

(*c*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[1]

(*d*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[1]

(*e*) *Float Test:* Standard Method of Sampling and Analysis of Cresote Oil (Serial Designation: D 38)[1] (Sections 17 and 18);

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[1]

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[1] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
HIGH-CARBON TAR CEMENT.[1]

Serial Designation: D 110 - 21 T.

These specifications are issued under the fixed designation D 110; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Scope. 1. These specifications cover material suitable for use in the construction of tar macadam and tar concrete pavements.

Properties. 2. The tar cement shall meet the following requirements:

(*a*) Water .... 0.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.) ...... 1.20 to 1.28

(*c*) Softening point[2] (Cube-in-Water Method) ..... 37.5 to 48°.9 C. (100 to 120° F.)[3]

(*d*) Distillation test:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)		0.00	per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)	not more than	2.00	"
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)	not more than	10.00	"
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)	not more than	20.00	"
Residue, by weight	not less than	80.00	"

(*e*) Specific gravity at 25°/25° C. (77°/77° F.) of total distillate to 300° C. (572° F.) .... not less than 1.03

(*f*) Softening point (Cube-in-Water Method) of residue from distillation test .... not more than 75° C. (167° F.)

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] If desired, a float test may be substituted for the softening point test, in which case the requirements shall be as follows: Float Test at 50° C. (122° F.), 100 to 300 sec.

[3] The specification range for softening point, within the above limits should be 10° F. for any given locality, for example, 100 to 110° F. for cold climates, equivalent in Float Test 100 to 200 sec.; 110 to 120° F. for warm climates, equivalent in Float Test 200 to 300 sec.

(*g*) Free carbon........................12.00 to 25.00 per cent

Methods of Testing.

3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[3]

(*d*) *Softening Point:* Standard Method of Tests for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[3]

(*e*) *Float Test:* Standard Method of Sampling and Analysis of Creosote Oil (Serial Designation: D 38)[3] (Sections 17 and 18);

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[3]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
LOW-CARBON TAR CEMENT.[1]

Serial Designation: D 111 – 21 T.

These specifications are issued under the fixed designation D 111; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Scope. 1. These specifications cover material suitable for use in the construction of tar macadam and tar concrete pavements.

Properties. 2. The tar cement shall meet the following requirements:

(*a*) Water..0.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.) ......1.16 to 1.19

(*c*) Softening point[2] (Cube-in-Water Method)......
37.5 to 48°.9 C. (100 to 120° F.)[3]

(*d*) Distillation test:

Total Distillate, by weight, 0 to 170° C. (32 to 338° F.)..................	0.00	per cent
Total Distillate, by weight, 0 to 235° C. (32 to 455° F.)..................not more than	2.00	"
Total Distillate, by weight, 0 to 270° C. (32 to 518° F.)..................not more than	10.00	"
Total Distillate, by weight, 0 to 300° C. (32 to 572° F.)..................not more than	20.00	"
Residue, by weight.................. not less than	80.00	"

(*e*) Softening point (Cube-in-Water Method) of residue from distillation test......................not more than 75° C. (167° F.)

(*f*) Free Carbon ....not more than 5.00 per cent

Methods of Testing. 3. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] If desired, a float test may be substituted for the softening point test, in which case the requirements shall be as follows: Float Test at 50° C. (122° F.), 100 to 210 sec.

[3] The specification range for softening point, within the above limits should be 10° F. for any given locality, for example, 100 to 110° F. for cold climates, equivalent in Float Test 100 to 155 sec.; 110 to 120° F. for warm climates, equivalent in Float Test 155 to 210 sec.

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[3]

(*d*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[3]

(*e*) *Float Test:* Standard Method of Sampling and Analysis of Creosote Oil (Serial Designation: D 38)[3] (Sections 17 and 18);

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[3]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS

FOR

COAL-TAR PITCH FOR BLOCK FILLER.[1]

Serial Designation: D 112 - 21 T.

These specifications are issued under the fixed designation D 112; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Properties. 1. The coal-tar pitch shall meet the following requirements:

(*a*) Water..0.00 per cent

(*b*) Specific gravity at 25°/25° C. (77°/77° F.)........1.23 to 1.33

(*c*) Softening point[2] (Cube-in-Water Method)......
46 to 57° C. (115 to 135° F.)

(*d*) Distillation test:

Total Distillate, by weight, 0 to 300° C.
(32 to 572° F.)..................not more than 10.00 per cent.
Residue, by weight...................... not less than 90.00 “

(*e*) Specific gravity at 25°/25° C. (77°/77° F.) of total distillate to 300° C. (572° F.)...........................not less than 1.03

(*f*) Softening point (Cube-in-Water Method) of residue from distillation test...................not more than 75° C. (167° F.)

(*g*) Ductility at 50 to 100 penetration, at 25° C. (77° F.).
not less than 50 cm.

NOTE.—The penetration of the pitch shall be brought within the range of 50 to 100 penetration by heating in an open vessel with frequent stirrings at a temperature of not over 350° F.

(*h*) Free carbon ....20.00 to 35.00 per cent

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

[2] The Softening Point (Cube-in-Water Method) specified should have a range of not over 10° F. within the above limits. The range, within the limits of 115 to 135° F. should vary with the use of the material, for example, if used in admixture with sand, in a northern locality or a southern locality. The softening point range, within the above limits, should also vary according to the character of the paving.

Methods of Testing.

2. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials:

(*a*) *Percentage of Water:* Tentative Method of Test for Water in Bituminous Materials (Serial Designation: D 114 - 21 T);[1]

(*b*) *Specific Gravity:* Tentative Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (Serial Designation: D 70 - 20 T);[2]

(*c*) *Distillation:* Standard Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (Serial Designation: D 20);[3]

(*d*) *Softening Point:* Standard Method of Test for Softening Point of Tar Products (Cube-in-Water Method) (Serial Designation: D 61);[3]

(*e*) *Ductility:* Tentative Method of Test for Ductility of Bituminous Materials (Serial Designation: D 113 - 21 T);[4]

(*f*) *Free Carbon:* Standard Method of Test for Soluble Bitumen (Serial Designation: D 4).[3]

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[1] See p. 706.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] 1921 Book of A.S.T.M. Standards.

[4] See p. 704.

TENTATIVE METHOD OF TEST
FOR
DUCTILITY OF BITUMINOUS MATERIALS.[1]

Serial Designation: D 113 - 21 T.

This method is issued under the fixed designation D 113; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Definition. 1. The ductility of an asphalt cement or semi-solid bitumen is the distance to which it will elongate before breaking when two ends of a briquette of the material are pulled apart at a specified rate of speed and at a specified temperature. When the conditions of the test are not specifically mentioned, the rate and the temperature are understood to be 5 cm. per minute at 25° C. (77° F.).

APPARATUS.

Mold. 2. The mold shall be as shown in Fig. 1. It shall be made of brass, the ends, b and b′, being known as clips, and the parts, a and a′, as sides of the mold. The dimensions of the mold shall be as follows:

Total length (internal)	7.45 - 7.55	cm.
Distance between clips	2.97 - 3.06	"
Width of clips at mouth	1.98 - 2.02	"
Width of briquette at minimum cross-section (half way between clips)	0.99 - 1.01	"
Thickness of briquette throughout	0.99 - 1.01	"

Water Bath. 3. The water bath shall be maintained at a temperature not varying more than 0°.1 C. from 25° C. (77° F.). The volume of water shall be not less than 10 liters and the sample shall be immersed to a depth of not less than 10 cm. and shall be supported on a perforated shelf not less than 5 cm. from the bottom of the bath.

Testing Machine. 4. Any apparatus may be used for pulling the briquette of bitumen apart that is so constructed that the briquette will be continuously immersed in water and the two clips pulled apart at a uniform rate of speed of 5 cm. per minute.

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[1] Criticisms of this Tentative Method are solicited and should be directed preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

PROCEDURE.

5. The asphalt cement or bituminous material to be tested shall be completely melted at such a temperature that it will be thoroughly fluid—with ordinary paving asphalt cement this is about 160° C. (320° F.). It shall then be strained through a 50-mesh sieve and, after a thorough stirring, poured into the mold. The mold shall be assembled on a brass plate and so as to prevent the material under test from sticking, the surface of the plate and the interior surfaces of the side pieces *aa'* of the mold shall be thoroughly amalgamated. In filling the mold care shall be taken not to disarrange the parts and thus distort the briquette. In filling, the material shall be poured in a thin stream back and forth from end to end of the mold until it is more than level full. It shall then be left to cool in the air at a temperature not lower than 15°.5 C. (60° F.), for 30 minutes, after which the excess of bitumen shall be cut off by means of a hot putty knife or spatula so that the mold shall be just level full. **Melting and Molding.**

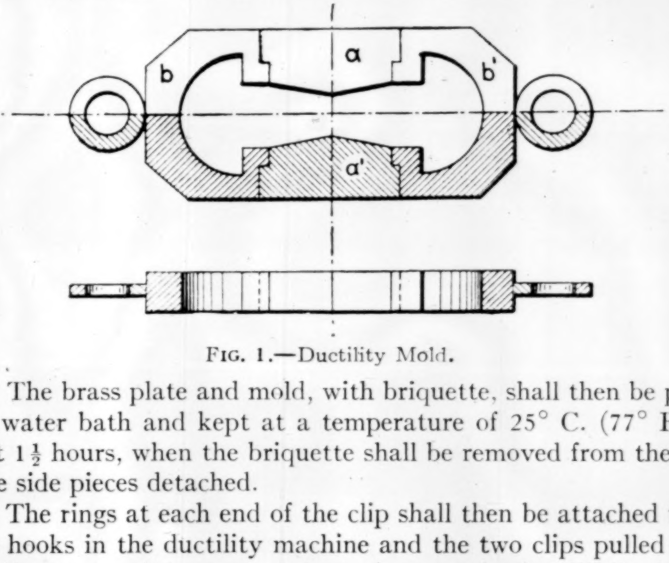

FIG. 1.—Ductility Mold.

6. The brass plate and mold, with briquette, shall then be placed in the water bath and kept at a temperature of 25° C. (77° F.) for at least 1½ hours, when the briquette shall be removed from the plate and the side pieces detached. **Keeping at Standard Temperature.**

7. The rings at each end of the clip shall then be attached to the pins or hooks in the ductility machine and the two clips pulled apart at a uniform rate of 5 cm. per minute (±5 per cent). While the test is being made, the water in the tank of the ductility machine shall cover the sample by at least 5 cm. and shall be kept continuously at a temperature within 0°.5 C. of 25° C. (77° F.). When the specimen of bituminous material breaks, the distance from the original position of the clip before pulling to its present position shall be measured, and shall be known as the ductility. The average of three tests shall be taken, excepting that any abnormal result shall be rejected. **Testing.**

TENTATIVE METHOD OF TEST
FOR
WATER IN BITUMINOUS MATERIALS.[1]

Serial Designation: D 114 - 21 T.

This method is issued under the fixed designation D 114; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Apparatus. 1. The apparatus shall consist of a copper still, 6 in. by 3½ in. inside diameter, with an adjustable ring burner to fit the still. The still shall be provided with a connecting tube, a condenser trough, a condenser tube, and a separatory funnel. A thermometer, 0 to 250° C., shall be provided. The apparatus shall be set up as shown in Fig. 1.

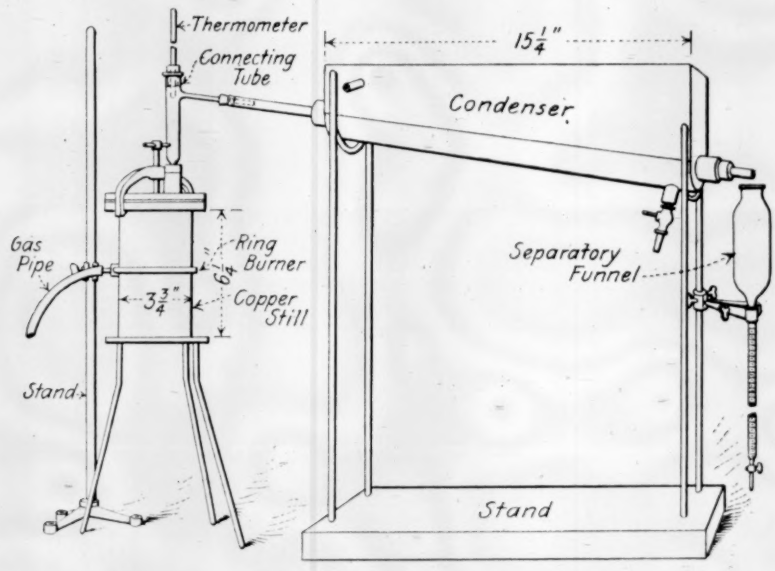
Thermometer
Connecting Tube
15¼"
Condenser
Gas Pipe
Ring Burner
6¼
3¾"
Copper Still
Separatory Funnel
Stand
Stand

FIG. 1

Procedure. 2. Fifty cubic centimeters of coal-tar naphtha or light oil shall be measured into a 250-cc. graduated cylinder, and 200-cc. of the material to be tested shall be added. In the case of petroleum products, petroleum naphtha may be substituted for the coal-tar naphtha. The contents shall be transferred to the copper still and the cylinder shall be washed with 100 to 150 cc. more of naphtha, and the washings added to the contents of the still. The lid and clamp shall be attached, using a paper gasket. The condenser trough shall be filled with water. Heat shall be applied by means of the ring burner, and the distillation continued until the vapor temperature has reached 205° C. (401° F.). The distillate shall be collected in the separatory funnel, in which 15 to 20 cc. of benzol or naphtha have been previously placed in order to effect a clean separation of the water and oil. The reading shall be made after twirling the funnel and allowing the contents to settle for a few minutes. The percentage shall be computed by volume. The naphtha or light oil used shall be tested to determine freedom from water.

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[1] Criticisms of this Tentative Method are solicited and should be directed, preferably before January 1, 1922, to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 25 W. Forty-third St., New York City.

3. The accuracy obtainable by this method is within 0.1 per cent. **Accuracy.**

4. Every precaution must be taken to insure a representative sample. Bituminous materials containing separated water are especially difficult to sample. **Precautions.**

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO COKE.[1]

Serial Designation: D 121 – 21 T.

These definitions are issued under the fixed designation D 121; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Coke.—The coherent cellular residue from the destructive distillation of coal and certain carbonaceous substances such as coal tar and petroleum pitches. It contains carbon as its chief constituent together with mineral matter and residual volatile matter.

Beehive Coke.—The coherent cellular residue from the destructive distillation of coal in beehive, rectangular, or similar forms of ovens, in horizontal beds covering the floor of the ovens. These ovens are generally heated by admission of a limited quantity of air, producing sufficient combustion to coke the coal in a specified time. In some instances heating flues are provided wherein a portion of the evolved gases are consumed. The underlying principle in the heating of the charge is internal combustion of the gases in the crown or dome of the oven which plays an important part as a means for storage of heat and radiation to the coking mass.

By-Product Coke.—The coherent cellular residue from the destructive distillation of coal in chambers or ovens substantially rectangular in section, the height and length of which are materially greater than the width. These ovens are generally heated by burning gas in flues in the oven walls, the gas being either part of the coke oven gas or derived from an external source. The underlying principle of the heating of the charge is external combustion, the heat so generated passing through the oven walls to the coking mass. Coke is the primary product, the volatile by-products being made available by suitable recovery apparatus.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr. A. C. Fieldner, Secretary of Committee D-6 on Coke, Fortieth and Butler Sts., Pittsburgh, Pa.

Gas House Coke.—The coherent cellular residue obtained as a by-product in the manufacture of gas by the destructive distillation of coal in retorts.

Foundry Coke from Beehive Ovens.—Coke which is physically and chemically suitable for use in foundry cupola practice, and may be either 72 or 48-hour coke. The principal difference between the two is the greater size of the 72-hour coke due to the thicker coal beds employed in its preparation. The breeze or fine coke smaller than approximately $\frac{3}{4}$ in. is forked or screened out.

Foundry Coke from By-product Ovens.—Coke which is physically and chemically suitable for foundry cupola practice which passes over a screening device having approximately $2\frac{1}{2}$-in. openings. It is not produced on any standard coking time.

Furnace Coke from Beehive Ovens.—Coke which is physically and chemically suitable for the reduction of iron ore in blast furnaces. The breeze or fine coke smaller than approximately $\frac{3}{4}$ in. is forked or screened out. The usual coking time on a normal working schedule is four 48-hour charges and two 72-hour charges.

Furnace Coke from By-product Ovens.—Coke which is physically and chemically suitable for reduction of iron ore in blast furnaces and which passes over a screening device with openings varying from $\frac{3}{4}$ to $1\frac{1}{2}$ in., depending on local conditions at different plants. It is not produced on any standard coking time.

Domestic Coke.—The smaller screened sizes, below approximately $2\frac{1}{2}$ in., suitable for use in domestic stoves, heaters, etc. The standard sizes are quite generally sold under the names given below and the screen sizes are average although locally varied somewhat:

NAME.	SCREEN SIZE.	
Egg Coke	Passing $2\frac{1}{2}$ in.	Retained on $1\frac{3}{4}$ in.
Stove Coke	" $1\frac{3}{4}$ "	" " $1\frac{1}{4}$ "
Nut Coke	" $1\frac{1}{4}$ "	" " $\frac{3}{4}$ "
Pea Coke	" $\frac{3}{4}$ "	" " $\frac{1}{2}$ "

Coke Breeze.—The fine coke smaller than $\frac{1}{2}$-in. mesh.

Dry Coke—Coke which has been dried to constant weight at temperatures not less than 104° C. nor more than 200° C. in the case of lump coke, and between 104 and 110° C. in the case of 60-mesh coke, in accordance with methods of determining moisture contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

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[1] 1921 Book of A.S.T.M. Standards.

Moisture.—The loss in weight sustained by heating coke in accordance with methods of determining moisture as contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Ash.—The incombustible residue remaining after ignition of coke to constant weight in an oxidizing atmosphere under conditions described under Determination of Ash contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Volatile Matter.—That part of the coal or coke which is driven off on heating in the form of tars and gases and is determined as the percentage loss in weight less the percentage of moisture sustained on heating coke in a covered platinum crucible for 7 minutes at a temperature of 950° C., in accordance with methods of determining volatile matter as contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Fixed Carbon.—The solid combustible residue remaining after heating coke in a covered platinum crucible for 7 minutes at 950° C., in accordance with methods of determining volatile matter as contained in the Standard Methods of Laboratory Sampling and Analysis of Coke (Serial Designation: D 37) of the American Society for Testing Materials.[1]

Fixed carbon = 100 per cent − (Percentage of moisture + percentage of ash + percentage of volatile matter).

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[1] 1921 Book of A.S.T.M. Standards.

TENTATIVE METHODS OF TESTING MOLDED INSULATING MATERIALS.[1]

Serial Designation: D 48 – 21 T.

These methods are issued under the fixed designation D 48; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1917; REVISED, 1921.

Material Covered. 1. These tests are intended to apply to all solid insulating materials that are formed in molds by the application of pressure, either with or without heat.

TENSILE STRENGTH.

Apparatus. 2. Any standard testing machine may be used. Special clips (see Fig. 1) of hardened steel shall be used, hung from links held in the jaws of the machine, so that the pull is central at all times, to avoid any transverse strain.

Specimen. 3. The standard test specimen shown in Fig. 1 shall be used for the tension test. It shall be molded in a hardened and ground steel mold to the dimensions given in Fig. 1.

Method. 4. (*a*) Five specimens shall be tested in the condition in which they are received.

Three specimens shall be tested after heating in an oven for one hour at a temperature which is 10° C. (18° F.) below the distortion point of the material, as determined in accordance with Sections 18 to 21. Each specimen shall be taken from the oven and tested immediately while hot.

Two specimens shall be tested after they have been entirely immersed in water for 48 hours at normal room temperature. The specimens shall be pulled apart at normal room temperature of about 20° C. (68° F.) after the surface water has been removed by wiping with a dry cloth.

(*b*) The test specimen shall be pulled apart at such a speed that the beam can be kept well balanced. All tests shall be made at normal room temperature of about 20° C. (68° F.). Measurements may be taken at intervals during the test to show the elongation of the specimen when required for elastic materials.

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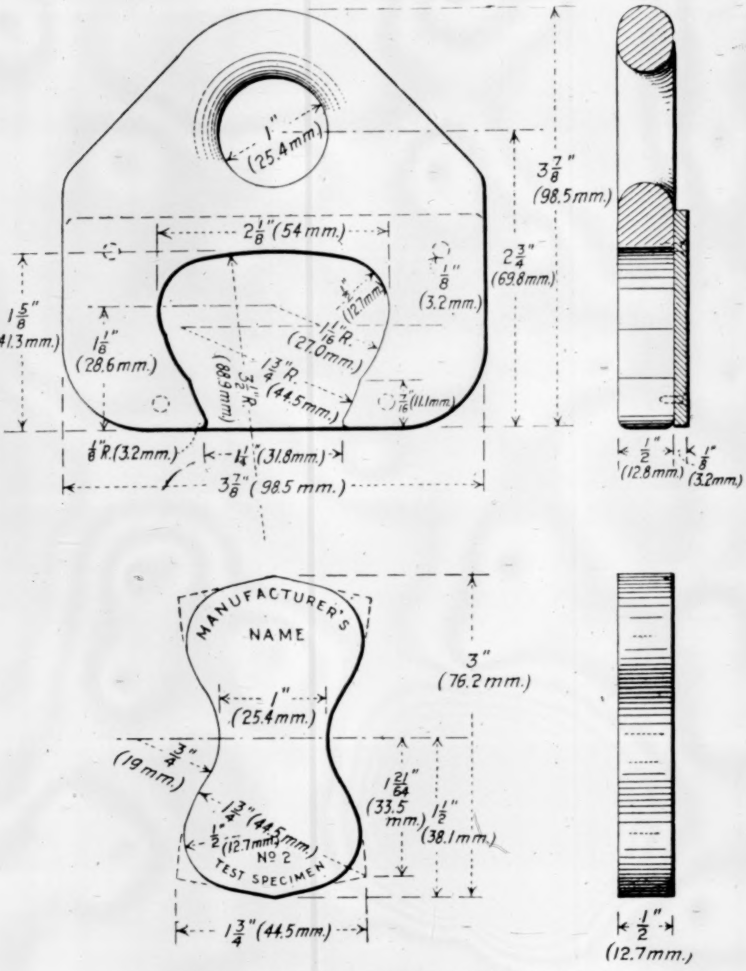
[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, 102 River Street, Newark, N. J.


1" (25.4 mm.)
3 7/8" (98.5 mm.)
2 3/4" (69.8 mm.)
2 1/8" (54 mm.)
1/2" (12.7 mm)
1/8" (3.2 mm.)
1 5/8" (41.3 mm.)
1 1/8" (28.6 mm.)
1 1/16" R. (27.0 mm.)
3 1/2" R. (88.9 mm.)
1 3/4" R. (44.5 mm.)
7/16" (11.1 mm.)
1/8" R. (3.2 mm.)
1 1/4" (31.8 mm.)
3 7/8" (98.5 mm.)
1/2" (12.8 mm.)
1/8" (3.2 mm.)
MANUFACTURER'S NAME
3" (76.2 mm.)
1" (25.4 mm.)
3/4" (19 mm.)
1 21/64" (33.5 mm.)
1 1/2" (38.1 mm.)
1 3/4" (44.5 mm.)
1/2" (12.7 mm.)
Nº 2
TEST SPECIMEN
1 3/4" (44.5 mm.)
1/2" (12.7 mm.)

Make Steel Mold to these Dimensions. Limits ± 0."002 (0.05mm.)

FIG. 1.—Tension Test Specimen (Specimen No. 2).

Report. 5. The report of test shall include:

(*a*) The breaking load of each specimen in pounds or kilograms;

(*b*) The thickness of each specimen in inches or centimeters as measured by a micrometer at the center of the specimen, that is, the point of minimum section.

(*c*) The ultimate tensile strength in pounds per square inch or in kilograms per square centimeter of each specimen, calculated from the minimum area measured at the center of the test specimen before the load is applied.

(*d*) The character of the material tested, with description of how it acts under stress.

(*e*) The speed in inches or centimeters per minute at which the jaws traveled during the test.

COMPRESSIVE STRENGTH.

6. Any standard testing machine may be used. The pressure head used for standard compressive strength tests of cement blocks is satisfactory for this purpose. A sheet of soft annealed, copper about $\frac{1}{32}$ in. (1 mm.) thick, or heavy blotting paper, shall be placed above and below the specimen to equalize irregularities. **Apparatus.**

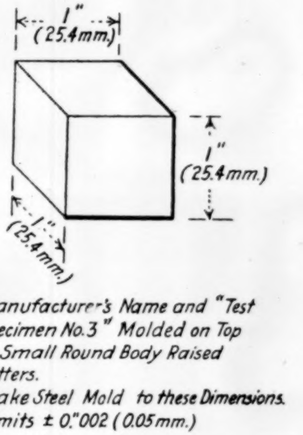

1"
(25.4mm.)
1"
(25.4mm.)
1"
(25.4mm.)
Manufacturer's Name and "Test Specimen No. 3" Molded on Top in Small Round Body Raised Letters.
Make Steel Mold to these Dimensions.
Limits ± 0."002 (0.05mm.)

FIG. 2.—Compression Test Specimen (Specimen No. 3).

7. The test specimen shall be molded in the form of a cube from a hardened steel mold, ground to the dimensions shown in Fig. 2. **Specimen.**

8. (*a*) Five specimens shall be crushed in the condition in which they are received. **Method.**

Three specimens shall be crushed after heating for one hour at a temperature which is 10° C. (18° F.) below the distortion point of the material as determined in accordance with Sections 18 to 21. Each specimen shall be taken from the oven and tested immediately while hot.

Two specimens shall be crushed after immersion in water at normal room temperature for 48 hours, with all surface water wiped off with a dry cloth.

(*b*) The load shall be applied in a direction at right angles to that in which the pressure was applied in molding, and at such a rate of speed that will permit the beam to be kept well balanced from zero load until the specimen is crushed. For the best results use the slowest possible speed.

Report. 9. The report of test shall include:

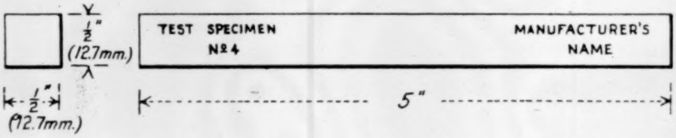
(*a*) The dimensions of each specimen in inches or in millimeters;

(*b*) The load in pounds or kilograms, on each specimen at the first sign of failure;

(*c*) The ultimate compressive strength in pounds per square inch or kilograms per square centimeter, of each specimen, calculated from the measured area of each specimen before the load is applied;

(*d*) The general character of the material tested, with description of how it acts under the applied load;

(*e*) The speed in inches or centimeters per minute at which the jaws traveled during the test.



Make Steel Mold to these Dimensions. Limits ± 0.″002 (0.05 mm.)

FIG. 3.—Transverse Test Specimen No. 4.

TRANSVERSE STRENGTH.

Apparatus. 10. Any standard testing machine may be used. The specimen shall be supported on two steel blocks, with corners rounded to $\frac{1}{16}$-in. (1.5-mm.) radius. These supports shall be not more than 4 in. (102 mm.) nor less than 2 in. (51 mm.) apart. The load shall be applied on top of the specimen in a direction at right angles to the direction in which the piece was molded, by means of a wedge-shaped pressure piece, the edge of which is rounded to a $\frac{1}{8}$-in. (3-mm.) radius, extending across the specimen with the edge parallel to the edges of the two supports. The angle of the wedge shall be approximately 45 deg. and the load shall be applied at right angles to the specimen midway between the supports. The specimen shall be laid flat upon the supports at equal distances from the edge at each end.

Specimen. 11. The test specimen shall be molded from a hardened steel mold, ground to the dimensions shown in Fig. 3.

Method. 12. (*a*) Four specimens shall be tested in the condition in which they are received.

Three specimens shall be tested after immersion in water at normal room temperature for 48 hours with all surface water wiped off with a dry cloth.

(*b*) The load shall be applied at as slow a speed as possible, so that the beam may be kept well balanced from zero load until the first sign of failure. All tests shall be made at room temperature of about 20° C. (68° F.). Measurements of the deflection may be taken for very elastic materials.

Report. 13. The report of tests shall include:

(*a*) The thickness and width of each specimen as measured by a micrometer in inches or millimeters;

(*b*) The load on each specimen in pounds or in kilograms at the first sign of failure;

(*c*) The maximum fiber stress in pounds per square inch or in kilograms per square centimeter calculated from the formula:

$$S=\frac{3}{2}\frac{Pl,}{bd^2}$$

in which S = maximum fiber stress, P = load applied, l = distance between the supports, b = width of specimen, and d = depth of specimen;

(*d*) The rate at which the load was applied;

(*e*) The amount of deflection at the center in inches or in millimeters;

(*f*) The distance between the supports in inches or in millimeters.

DIELECTRIC STRENGTH.

Apparatus. 14. (*a*) Any well-designed high tension transformer connected to an alternating current supply having as nearly a true sine wave as possible, may be used. The transformer and the source of supply of energy shall be not less than 2 kva. for voltages of 50,000 volts or less, and not less than 5 kva. for voltages above 50,000 volts. The frequency shall not exceed 100 cycles per second.

(*b*) Regulation shall be so controlled that the high tension testing voltage taken from the secondary of the testing transformer can be raised gradually from any point and in no case more than 500 volts at a step. The control may be made by generator field regulation, with an induction regulator, or with a variable ratio auto transformer. Any method of regulating the voltage is satisfactory which does not distort the wave more than ten per cent from a sinusoidal shape.

(*c*) The voltage may be measured by any approved method which gives root-mean-square values, preferably by means of a voltmeter connected to a special voltmeter coil in the high tension winding of the testing transformer or to a separate step-down instrument potential transformer. A voltmeter on the low tension side of the transformer is satisfactory, if the ratio of transformation does not change under any test condition. An electrostatic voltmeter properly calibrated in the high tension circuit is also satisfactory. A spark gap may be used to check the readings at very high potentials.

Some protection is desirable in the high tension circuit of testing transformers where the voltage is from 25,000 to 100,000 volts, to prevent dangerous surges and limit the current when the test specimen is punctured. It is, however, desirable to have as much energy available as possible when puncture occurs. If impedance in the form of choke coils be used in series with the high tension terminals, it should not be greater than that which will limit the high tension current to double the normal rated current of the testing transformer.

When a spark gap is used, a non-inductive resistance of about one ohm per volt may be inserted in series with one terminal of the spark gap, to damp high frequency oscillations at the time of breakdown and limit the current flow. This resistance shall be as near the gap as possible. If the test is made with one side grounded, this resistance shall be on the ungrounded side of the circuit, and if neither side is grounded the resistance shall be inserted one-half on each side of the spark gap. Water tube resistors are preferable to carbon for this purpose, as carbon resistance may be materially decreased by the passage of current.

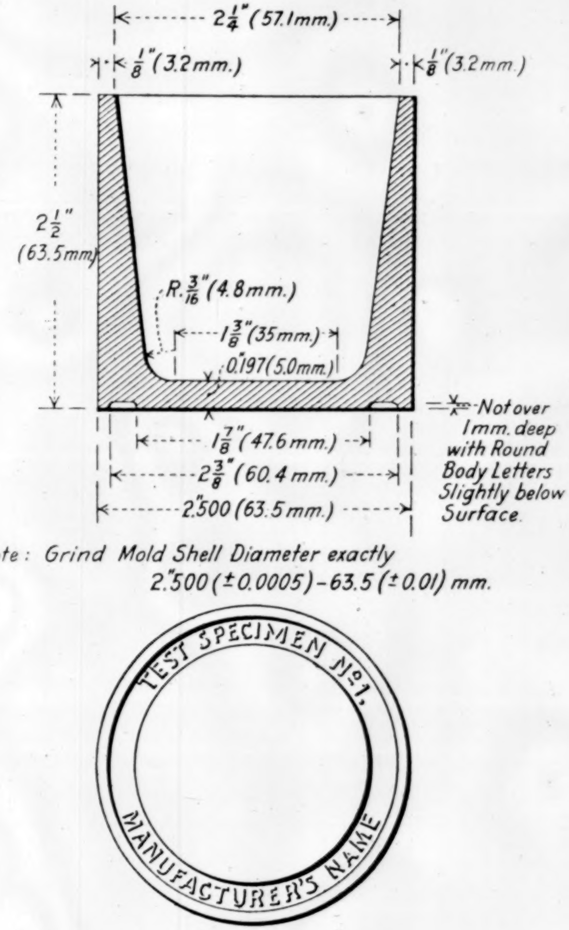
(*d*) The apparatus used and the method of measuring the voltage shall meet the requirements of the standardization rules of the American Institute of Electrical Engineers.

Specimen. 15. The test specimen shall be molded to the dimensions shown in Fig. 4. The mold shall be hardened and ground to these dimensions. If the material cannot be molded to the full height shown, the height may be reduced to $1\frac{1}{4}$ in. (31.7 mm.).

For materials having a puncture value higher than 300 volts per mil, the thickness of the bottom of the specimen may be reduced to 0.098 in. (2.5 mm.). It should be noted, however, that the apparent dielectric strength in volts per mil may be increased as much as 50 per cent when the thickness of the bottom of the specimen is so reduced.

Method. 16. (*a*) Voltage shall be applied to the test specimen by floating the specimen on mercury and placing a pool of mercury about $\frac{1}{8}$ in. (3 mm.) deep inside the specimen.

It is recommended that all tests be made in air, but whenever it is impossible to puncture the specimen in air without arcing over the edge, it shall be immersed in high grade transformer oil. On specimens which require a very high voltage to puncture, it may be necessary to put a glass tube or shield over the wire leading to the mercury on the inside of the specimen in order to prevent breakdown over the surface of the oil between terminals. The testing voltage shall be raised at a constant rate of approximately one thousand volts per second until puncture occurs.


2¼" (57.1mm.)
⅛" (3.2mm.)
⅛" (3.2mm.)
2½" (63.5mm)
R. 3/16" (4.8mm.)
1⅜" (35mm.)
0.197 (5.0mm.)
Not over 1mm. deep with Round Body Letters Slightly below Surface.
1⅞" (47.6mm.)
2⅜" (60.4 mm.)
2.500 (63.5mm.)
TEST SPECIMEN No. 1.
MANUFACTURER'S NAME

Note: Grind Mold Shell Diameter exactly 2.500 (±0.0005) - 63.5 (±0.01) mm.

Make Steel Mold to these Dimensions. Limits ±0.002 (0.05mm.)

FIG. 4.—Test Specimen No. 1 for Dielectric Strength.

(*b*) Five specimens shall be punctured in the condition received at normal room temperature of about 20° C. (68° F.) in order to determine the uniformity of the molded material.

Three specimens shall be punctured after heating one hour in an oven heated to 10° C. (18° F.) below the distortion point of the material as determined in Sections 18 to 21. The specimen shall be taken from the oven and immediately punctured in air while hot. This test is intended to cover all molded materials which do not withstand working temperatures above 125° C. (257° F.). Tests on materials which resist high temperatures may be made above 125° C. (257° F.) when required.

Two specimens shall be punctured after they have had the rim immersed in melted paraffin for a depth of 1 in. (25.4 mm.) and have been entirely immersed in water for 48 hours at normal room temperature of about 20° C. (68° F.). The surface of the specimen shall be wiped off with a dry cloth to remove all trace of excessive surface moisture and the puncture test immediately made.

(*c*) The results from specimens where puncture takes place up on the side of the specimen instead of through the bottom shall be discarded. Experience shows that very plastic materials which flow easily in the mold always puncture through the bottom, while materials which do not mold readily will often puncture through the side walls of the specimen at some distance up from the bottom.

Report. 17. The report of test shall include:

(*a*) The thickness of the bottom of each specimen measured with a micrometer in the direction perpendicular to the bottom surface, and also the thickness at the point of puncture, regardless of the path taken by the discharge. The thickness of each specimen shall be given in mils or in millimeters;

(*b*) The puncture voltage of each test specimen expressed in terms of the effective (root-mean-square) value;

(*c*) The volts per mil or per millimeter as calculated from the measured thickness of the bottom of the specimen;

(*d*) The general character of the material tested with regard to leakage, if any is observed.

DISTORTION UNDER HEAT.

Apparatus. 18. A special apparatus shall be used for this test as shown in Fig. 5. The specimen is supported on steel supports, 4 in. (102 mm.) apart with the load applied on top of the specimen vertically and midway between the supports, the same as for the transverse test, Section 10. The machine shall be arranged to apply a load of $5\frac{1}{2}$ lb.

(2.5 kg.). The specimen shall be placed in an air bath surrounded by an oil bath which is so arranged that its temperature may be raised gradually. The machine shall be so arranged that the deflection of the specimen at its center between the supports can be measured on a scale in mils or millimeters and shall be equipped with a thermometer so that the temperature of the specimen can be recorded at any time. The machine may be arranged to automatically shut off the heat and sound an alarm as soon as the required deflection is reached.

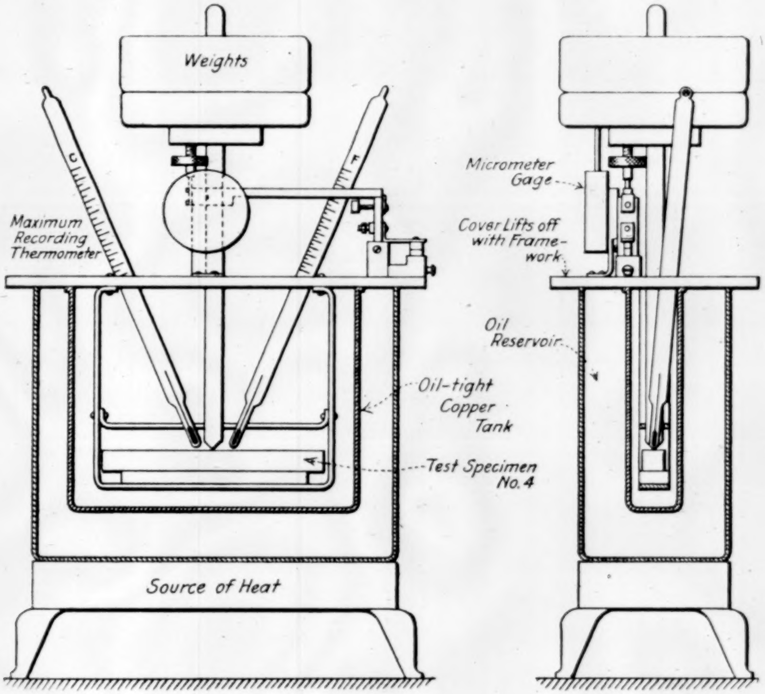

Weights
C
F
Maximum Recording Thermometer
Oil-tight Copper Tank
Test Specimen No. 4
Source of Heat
Micrometer Gage
Cover Lifts off with Frame-work
Oil Reservoir

FIG. 5.—Machine for Temperature Tests.

Specimen. 19. The same test specimen shall be used for this test as required for the transverse strength test, Section 11, molded from a hard steel mold ground to the dimensions given in Fig. 3.

Method. 20. Three test specimens shall be tested in the condition in which they are received, starting at normal room temperature of about 20° C. (68° F.) and increasing the temperature gradually at the rate of approximately 1° C. every two minutes.

The distortion point shall be considered the temperature at which the specimen has deflected 10 mils (0.254 mm.) at the center between the supports.

Report. 21. The report of test shall include:

(*a*) The breadth and depth of each specimen measured at the center with a micrometer in inches or in millimeters;

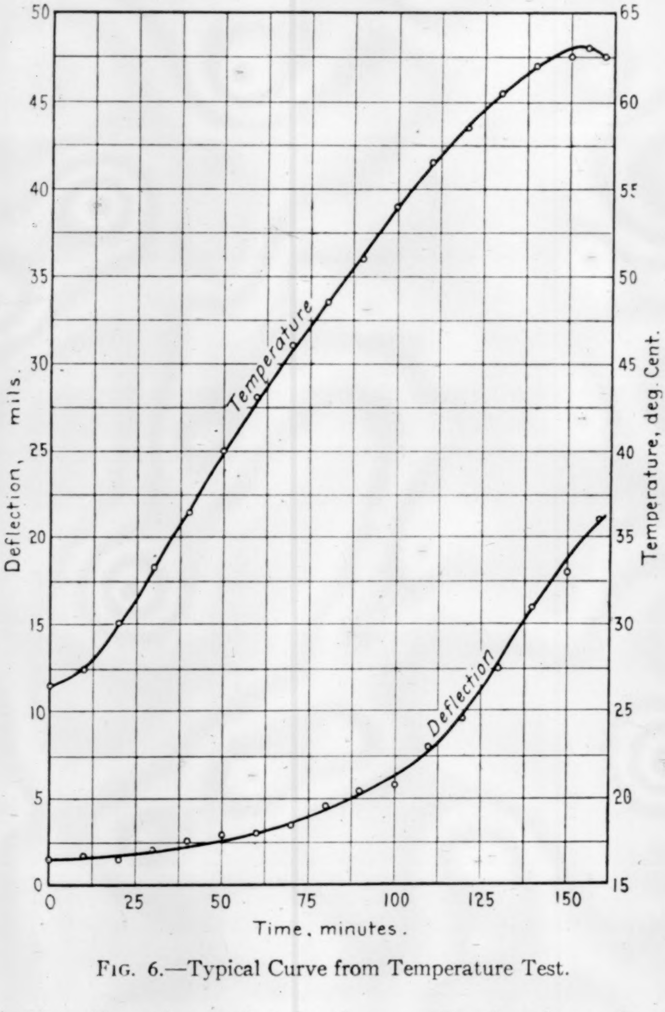


FIG. 6.—Typical Curve from Temperature Test.

(*b*) The distortion point in degrees Centigrade or in degrees Fahrenheit;

(*c*) The length of time in minutes required for each specimen to deflect 10 mils (0.254 mm.);

(*d*) Any peculiar characteristics of the material as noted either during the test or after the specimen is removed from the machine;

(*e*) A curve for each test specimen showing the time in minutes horizontally and the amount of deflection and also the temperature at given intervals, as vertical ordinates as shown in Fig. 6.

EFFECT OF MOISTURE.

Apparatus. 22. Any good chemical balance, a beaker of water at normal room temperature of about 20° C. (68° F.), and an oven of any standard make capable of maintaining a uniform temperature of 100° C. (212° F.) with a variation allowed of ±5° C.

Specimen. 23. The test specimen No. 1 shown in Fig. 4 shall be used for this test. After the puncture tests prescribed in Section 16 (*b*), are completed on the five specimens, three of them shall be taken and the entire rim of each specimen shall be sawed off with a hack saw $\frac{1}{4}$ in. (6 mm.) back from the top edge of the specimen so as to expose a more or less uniformily cut surface.

Method. 24. Weigh each of the three test specimens after the rim has been sawed off. If the material softens readily at moderate temperatures, the specimen may be placed in a desiccator for 24 hours, or in an oven at a temperature of 50° C. (122° F.), permissible variation ±5° C., for 24 hours. For materials which do not soften readily, the specimen shall be placed in an oven heated to 100° C. (212° F.), permissible variation ±5° C., for 24 hours. After drying, the pieces shall be cooled in a desiccator and weighed again at normal room temperature. The specimens shall be placed in water, wholly immersed, for 100 hours at normal room temperature. They shall then be removed from the water at the end of 100 hours, all surface water wiped off with a dry cloth, and the specimens weighed immediately.

Report. 25. The report of test shall include:

(*a*) The original weight of each specimen;

(*b*) The dry weight of each specimen;

(*c*) The weight of each specimen after immersion for 100 hours;

(*d*) The percentage of moisture contained in each test specimen as received, and the percentage of moisture absorbed during the 100 hours, taking the dry weight as 100 per cent.

All weights shall be given in grams.

TENTATIVE METHODS OF TESTING INSULATING VARNISHES.[1]

Serial Designation: D 115 – 21 T.

These methods are issued under the fixed designation D 115; the final number indicates the year of original issue, or in case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These tests are intended for varnishes which are applied by brushing, dipping or spraying, and are primarily for the purpose of providing electrical insulation.

SPECIFIC GRAVITY.

Specific Gravity. 2. The specific gravity shall be measured with a pyknometer, Westphal balance or with a hydrometer so graduated that the specific gravity can be determined to 0.001. The temperature of the varnish shall be not less than 18° C. (64°.4 F.) nor more than 22° C. (71°.6 F.) and corrected to 20° C. (68° F.) by applying a correction of 0.0007 per 1° C. (0.0004 per 1° F.).

VISCOSITY.

Viscosity. 3. (*a*) The viscosity shall be determined with a MacMichael, Stormer or other suitable type of instrument. The short-tube type of viscosimeter usually employed for lubricating oils is not acceptable. The temperature of the varnish shall be 20° C. (68° F.).

(*b*) The report shall include such details as the kind of instrument used, the size of the counterweight if a Stormer instrument is used, or the size of the wire in case the MacMichael instrument is used, etc.

FLASH AND FIRE POINTS.

Apparatus. 4. (*a*) The flash point shall be measured with a closed-cup tester and the fire point with an open-cup tester.

(*b*) The type of tester shall be stated in the report.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, 102 River St., Newark, N. J.

Procedure for Flash and Fire Points.

5. The rate of heating shall be about 2 to 3° C. (3.6 to 5°.4 F.) per minute for low flash point varnishes and about 5 to 8° C. (9 to 14° F.) per minute for high flash point varnishes. The test flame shall not be applied oftener than once every 3° C. (5°.4 F.) for low flash point varnishes; or 5° C. (9° F.) for high flash point varnishes. The first application of the test flame shall be at a temperature not lower than 10° C. (18° F.) below the flash point. The test flame shall be applied at a distance of about 1 cm. (0.394 in.) from the surface of the varnish.

TIME OF DRYING.

Test Specimen.

6. (*a*) Specimens for this test shall be pieces of thoroughly cleaned, smooth sheet copper or brass about 3 cm. (1.18 in.) wide and 20 cm. (7.88 in.) long and about 0.127 mm. (0.005 in.) thick.

(*b*) The specimens shall be dipped once in the varnish and withdrawn slowly and uniformly (about 15 in. (38 cm.) per min.). The consistency of the varnish shall be first so adjusted by trial that the thickness of the film of varnish on each side of the metal shall be between 0.022 mm. (0.0009 in.) and 0.026 mm. (0.001 in.).

Procedure.

7. (*a*) Specimens of air-drying varnish shall be dried in free air at a room temperature of approximately 20° C. (68° F.).

(*b*) In the case of baking varnishes, six specimens shall be dipped and allowed to drain for 30 minutes at a room temperature of approximately 20° C. (68° F.) and then dried in free air in an oven at approximately 100° C. (212° F.). At the end of the first 30 minutes, and again at the end of each 10-minute period thereafter, one specimen shall be taken from the oven and examined.

Time of Drying.

8. The varnish shall be considered dry when a specimen will not stick to itself when folded and pressed together between the thumb and finger at a temperature of approximately 20° C. (68° F.).

DIELECTRIC STRENGTH TEST.

Dielectric Strength Test Specimen.

9. (*a*) Specimens for the dielectric strength test shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 20 cm. (7.88 in.) square and about 0.127 mm. (0.005 in.) thick into the varnish which shall be at the consistency prescribed in Section 6 (*b*).

(*b*) Each specimen shall be dipped four times as specified in Section 6 (*b*), once in each direction, in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish shall be dried in free air at a room temperature of approximately 20° C. (68° F.) for a period 25 per cent longer than that found in Section 8.

(*d*) Specimens of baking varnish shall be drained and then baked for a period 25 per cent greater than that found in Section 8.

(*e*) The final thickness of the film of varnish on each side of the specimen shall be between 0.089 mm. (0.0035 in.) and 0.102 mm. (0.004 in.).

Procedure. 10. (*a*) The dielectric strength of the two films of varnish shall be determined by applying alternating potential to two circular metal disks, 3 cm. (1.18 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). The potential shall be applied at a low value and gradually raised at a rate of approximately 500 volts per second until puncture occurs. Ten such punctures are to be made at various points selected at random on each specimen. In each test the thickness of the films of varnish is to be determined as close to the point of puncture as practicable.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined, and the voltage shall be measured by methods approved by the American Institute of Electrical Engineers.[1]

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 500 volts. The apparatus shall comply with the Standardization Rules of the American Institute of Electrical Engineers.[1]

Dielectric Strength. 11. The volts at puncture, the net thickness of insulation and the volts per mil of net thickness shall be reported for each of the ten tests together with the average maximum amd minimum volts per mil.

WATER ABSORPTION TEST.

Procedure. 12. Specimens similar to those described in Section 9 shall be immersed in water at a room temperature of approximately 20° C. (68° F.) for a period of 24 hours. Upon removal from the water, the surface water shall be wiped off and dielectric strength tests made immediately as described in Section 10.

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[1] Standards of the American Institute of Electrical Engineers.

Dielectric Strength. 13. The volts at puncture, the net thickness of the insulation and the volts per mil of net thickness shall be reported for each of the ten tests, together with the average, maximum and minimum volts per mil.

HEAT ENDURANCE TEST.

Test Specimen. 14. For the heat endurance test, a specimen shall be prepared as in Section 9. After first removing not less than 1.27 cm. (0.5 in.) from one edge, 7 strips shall be cut from the same edge, each 1.9 cm. (0.75 in.) wide.

Procedure. 15. (*a*) Six of the seven specimens prepared for this test shall be placed in a uniformly heated oven in which the temperature is maintained at 100° C. (212° F.) within ±5° C. (9° F.). A specimen shall be removed at the end of 50, 100, 200, 300, 400 and 500 hours respectively and, together with the initial specimen, shall be tested as follows at a room temperature of approximately 20° C. (68° F.).

(*b*) Each specimen shall be bent through 180 deg. over rods of 0.64 cm. ($\frac{1}{4}$ in.), 0.48 cm. ($\frac{3}{16}$ in.) and 0.32 cm. ($\frac{1}{8}$ in.) diameters respectively, beginning with the largest and using each time a part of the specimen which has not been previously bent. The diameter of the rod at which the first crack in the insulation occurs shall be noted and reported.

ACID AND ALKALI PROOF TEST.

Test Specimens. 16. The specimens to be used for the test for acid and alkali proofness shall be brass rods 1.5 cm. (0.59 in.) in diameter, 15 cm. (5.90 in.) long and carefully rounded at one end to a radius of 0.75 cm. (0.295 in.). These specimens shall be dipped three times into the varnish, leaving exposed about 3 cm. (1.18 in.) of the rod at the end opposite the rounded end. Each coat shall be dried 25 per cent longer than the period determined in Section 8. Three specimens each shall be prepared for the acid and alkali solutions.

Procedure. 17. (*a*) The three specimens shall be suspended in the acid or alkali whose effect it is desired to determine to within 3 cm. (1.18 in.) of the end of the coated portion of the rod and suitable provision made for detecting the change in the electrical resistance between the rod and the solution. (Note 1.)

(*b*) It is recommended that these tests be made in 10-per-cent solutions as follows:

Sulfuric acid of sp. gr. 1.069 at 60° F. (15°.5 C.) or Nitric acid of sp. gr. 1.056 at 60° F. (15°.5 C) or Hydrochloric acid of sp. gr. 1.050 at 60° F. (15°.5 C.) and Sodium Hydroxide of sp. gr. 1.115 at 60° F. (15°.5 C.).

(*c*) The temperature of the solution shall be kept at approximately 20° C. (68° F.).

NOTE 1. A simple method is to connect a voltmeter between each rod in turn and one side of a 110-volt direct current circuit, the other side of the circuit being connected to the solution through any piece of suitable metal suspended in the solution. The resistance will be inversely proportional to the deflection of the voltmeter pointer, that is, the smaller the deflection, the greater the resistance. Failure of the material will, therefore, be indicated by a sudden increase in the deflection of the voltmeter pointer.

Acid and Akali Proofness. 18. The resistance between each rod and the solution shall be measured once per day and the number of days elapsing before breakdown occurs shall be taken as the "proofness" of the varnish.

OIL TEST.

Oil Test Specimen. 19. For the test for the effect of oil, pieces cut from the specimens prepared for the dielectric strength test (Section 9) may be used after they have been punctured and measured.

Procedure. 20. The effect of oil on the varnish shall be determined by immersing the specimens in transformer oil at a temperature of 100° C. (212° F.) for 48 hours and noting the effect on the varnish as indicated, for example, by wiping with a piece of dry white cloth.

TENTATIVE METHODS OF TESTING ELECTRICAL PORCELAIN.[1]

Serial Designation: D 116 – 21 T.

These methods are issued under the fixed designation D 116; the final number indicates the year of original issue or in case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These tests are intended to apply to porcelain which is to be used for electrical insulating purposes.

I. TENSILE STRENGTH.

Apparatus. 2. Any standard testing machine may be employed, but it shall be of suitable capacity.

Preparation of Test Specimens. 3. Test specimens may be prepared by pugging or extruding rolls of suitable size, throwing rolls by hand or by cutting rolls from pugged blocks. For comparative tests one method of preparing specimens should be adhered to, as test specimens prepared by different processes show different results. They shall be turned in the green condition to such dimensions as will give fired pieces of standard size, shrinkage being determined and allowed for as in regular ceramic practice. Variation from the standard dimension shall be kept within ± 5 per cent, as it has been found that the strength per square inch calculated from results obtained with test specimens of about 0.2 sq. in. increases about 0.5 per cent for a decrease in area of 1 per cent.

Test specimens shall be fired in saggars on end, either on placing sand or clay bats. They shall not be buried in sand as this will cause the pieces to break in firing. Firing shall be carried out in the regular porcelain kilns. Specimens which have warped in firing shall be rejected because they will give unreliable results and therefore a sufficient number of specimens should be prepared to give the required number of satisfactory ones.

Specimens. 4. (*a*) *Ohio Brass Co. Method.*—The test specimens shall have the shape and dimensions shown in Fig. 1.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1st, 1922, to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, 102 River St., Newark, N. J.

(*b*) *Jeffry-Dewitt Insulator Co. Method.*—The test specimens shall have the shape and dimensions shown in either Fig. 2 or Fig. 3. The maximum cross-section area in the reduced section of the specimen shall be not greater than 0.2 sq. in.

When dry, the shoulder of the specimens shall be glazed, leaving the reduced section free from glaze.

NOTE.—The glaze is necessary to obtain uniform results and insure that failure occurs in testing in the reduced section. The glaze is omitted from the reduced section in order to avoid variation in strength which may be attributable to the glaze.

Mounting of Specimens.

5. (*a*) *O.B. Method.*—The method of mounting the test specimen in the specimen holders is shown in Fig. 4. The method of using the assembly jig shown in the figure is as follows: The test specimen is calipered at the small section. The tapered jig, *G*, with the arbor, *E*, is then placed in the guides, *V*. The point on the tapered piece, *G*, which has the same diameter as the minimum section on the specimen is placed directly over the V-notched block, *N*. This piece is then raised until it comes in contact with the piece, *G*, and the wing nut, *S*, tightened. *E* and *G* are then removed and the cap pieces, *C*, screwed on to the rods, *R*, which are laid in the notches *V*-*V*. The center of the specimen is placed in the V-notched block, *N*, and the clamping piece, *L*, tightened down to hold it in place.

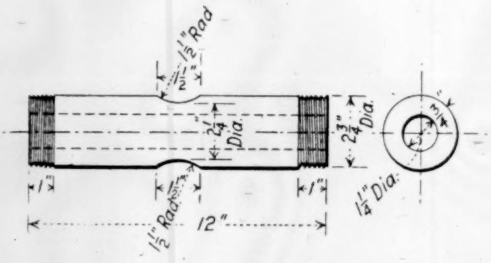

FIG. 1

One of the caps, *C*, with the attached rod, *R*, can then be moved over the end of the specimen and held in place by tightening the strap, *H*; the whole assembly apparatus is then stood on one end and the cap moved so as to allow filling with cement. The cap is then moved up in place, rotating it at the same time so as to properly work in the cement. The strap, *H*, is then tightened and the piece left undisturbed until the cement hardens.

When the cap has been attached at one end, the assembly apparatus can be stood on the other end and the other cap cemented in place.

NOTE.—This arrangement permits of setting up the jig properly and easily for specimens which vary slightly in diameter and insures keeping the center line of the specimen in the center line of the caps. A slight tip of the specimen will be unimportant so long as both caps can be assembled to the specimen.

After the cement has hardened (which will not require more than five or ten minutes if litharge cement is used), the specimen, can be removed and eyes screwed into caps in place of the rods, *R*.

(*b*) *J-D Method.*—The method of mounting the test specimen in this method of testing is as follows:

Test Specimen, Fig. 2 (Conical Ends).—The specimen shall be held by small steel clamps, Fig. 5, each consisting of a split bushing, *B*, ground to fit the test specimen, *T*, and held by a collar, *C*, the load being applied by the plate, P_1, held in slots of the jaws of the testing machine through the ball and socket joint, *J*. The soft gasket, *G*, of blotting paper shall be inserted between the porcelain and the bushing to distribute the load. A new gasket shall be used with each specimen.

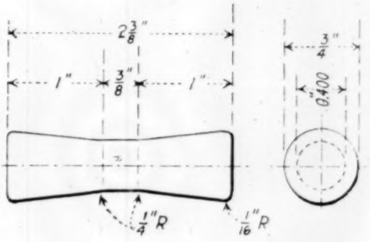

FIG. 2

Test Specimen, Fig. 3 (Dumb-bell Ends).—The specimen is held by a split ring, *R*, Fig. 6, with the same radius of curvature as the shoulders of the specimen. This ring fits into a recess in plate P_2 which, in turn, fits into the slots in the jaws of the testing machine.

NOTE.—No gasket is required with this piece when the shoulders are glazed, Satisfactory results have not been obtained with unglazed pieces, even when using a gasket. This form of specimen has the advantage of requiring no gasket and so is more rapid in manipulation and of allowing greater variation in dimensions.

Method.

6. (*a*) Not less than 10 specimens (preferably more) shall be tested in the normal condition.

(*b*) The specimen shall be pulled apart at such a constant speed that the beam of the testing machine can be kept well balanced at all loads.

(*c*) When failure occurs outside of the reduced section, that result shall be discarded.

(*d*) The tests shall be made at a room temperature of about 20° C. (68° F.).

Report. 7. The report shall include the following:

(*a*) The diameter in inches or centimeters as measured by a micrometer at the point of fracture.

(*b*) The breaking load of each specimen in pounds or in kilograms.

(*c*) The ultimate strength in pounds per square inch or in kilograms per square centimeter of each specimen as calculated from the actual area of the specimen measured at the point of fracture.

(*d*) The average of the results given in Paragraph (*c*).

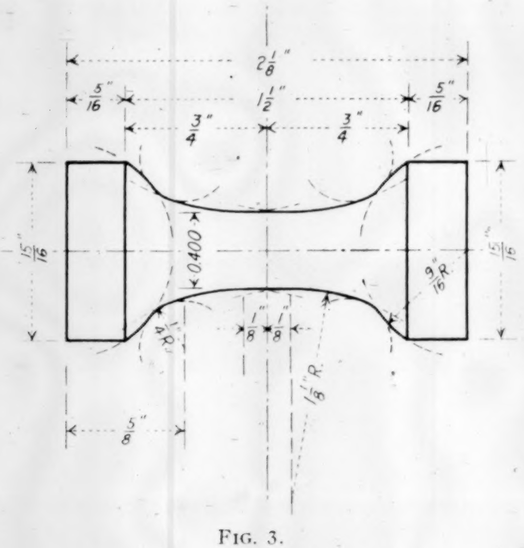

FIG. 3.

(*e*) The character of the material tested and a description of its behavior under stress.

(*f*) The speed in inches or centimeters per minute at which the jaws traveled during the test.

II. COMPRESSIVE STRENGTH.

Apparatus. 8. Any standard testing machine may be used. A contact pad or cushion of $\frac{1}{32}$ in. of blotting paper shall be placed between the upper and lower faces of the specimens and the heads of the testing machine to equalize irregularities in the surfaces. Fresh cushions shall be used for each specimen tested.

Specimens. 9. The test specimen shown in Fig. 7 shall be used for the compressive strength test.

Method.

10. (*a*) Not less than 10 specimens (preferably more) shall be tested in the condition in which they are received.

(*b*) The load shall be applied at that constant rate of speed which will permit the beam to be kept well balanced at all loads.

(*c*) The test shall be made at a room temperature of about 20° C. (68° F.).

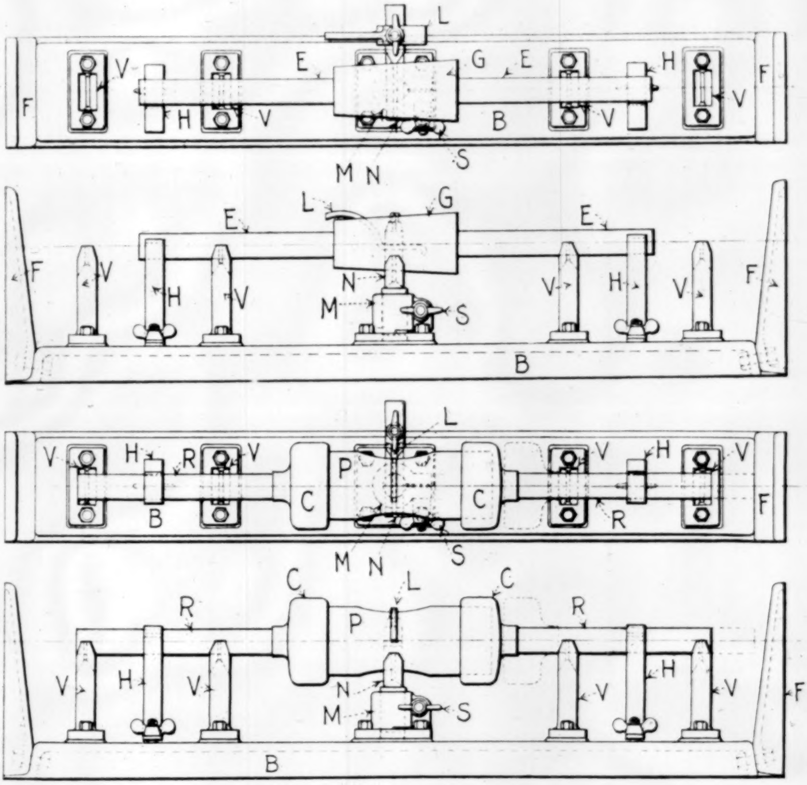

FIG. 4.

Report.

11. The report shall include the following:

(*a*) The dimensions of each specimen in inches or in millimeters.

(*b*) The load in pounds or kilograms on each specimen at the first sign of fracture.

(*c*) The ultimate compressive strength in pounds per square inch or in kilograms per square centimeter for each specimen calculated from the measured area before the load is applied.

(*d*) The average of the results given in Paragraph (*c*).

(*e*) General character of the material tested and a description of its behavior under load.

(*f*) The speed in inches or in centimeters at which the jaws traveled during the test.

III. RESISTANCE TO IMPACT.

Apparatus. 12. The test shall be made with the apparatus shown in Fig. 8.

Specimens. 13. The test specimen shown in Fig. 7 shall be used for impact tests.

Method. 14. (*a*) The specimen shall be placed on the base of the device directly under the hammer with a disk of blotting paper on the top of the specimen. The collars shall be set for a 6-in. drop of the hammer. The hammer shall be raised to the stops and allowed to fall unimpeded upon the specimen. A fresh disk of blotting paper shall be used for each blow of the hammer.

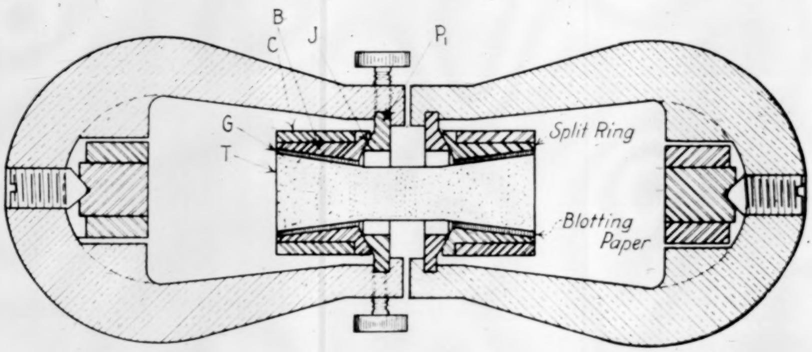

FIG. 5.

(*b*) The entire hammer shall weigh 1.87 lb. (850 g.).

(*c*) If the specimen remains unbroken after 20 blows of the hammer using the 6-in. drop, the drop shall be increased to 7 in. and the test repeated. If the specimen remains unbroken after 20 blows using the 7-in. drop, the distance shall be increased to 8 in. and the test repeated. If necessary, increasing the height 1 in. per 20 blows shall be continued until the specimen breaks.

(*d*) Not less than five specimens shall be tested in the condition in which they are received.

Report. 15. The report shall include a statement of the number of blows required to break each specimen with a 6-in. fall of the hammer or, if failure did not occur with the 6-in. drop, the total number of blows and heights of drop necessary to fracture each specimen.

IV. DIELECTRIC STRENGTH.

Apparatus. 16. The apparatus shall be as described in Section 14 of the Tentative Methods of Testing Molded Insulating Materials (Serial Designation: D 48 - 21 T) of the American Society for Testing Materials.[1]

Specimens. 17. The specimens shall be as shown in Fig. 1 except that the threads may be omitted.

Method. 18. (*a*) *Porcelain for all purposes.*—A pad of wet clay about $\frac{1}{4}$ in. thick shall be laid in the groove and a lining of wet clay about $\frac{1}{4}$ in. thick put on the inside of the specimen. The potential shall be applied to these two pads of clay by any suitable means. Mercury may be substituted for the wet clay if desired. The test should preferably be made in air but it may be made in transformer oil if necessary.

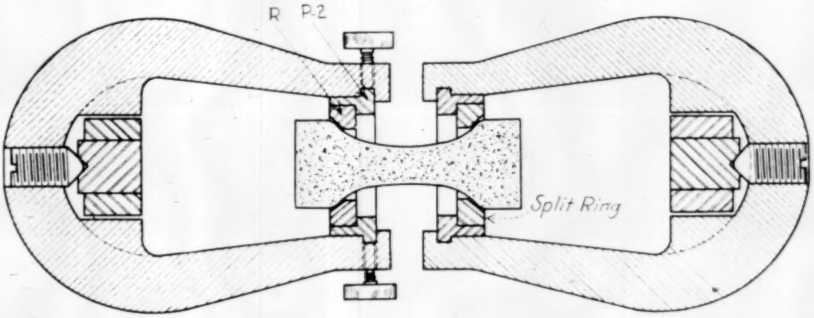

FIG. 6.

Not less than ten specimens shall be punctured in their normal condition at a normal room temperature of about 20° C. (68° F.).

(*b*) *Porcelain for transmission line insulators.*—In addition to the test prescribed in Paragraph (*a*), not less than 10 specimens shall be tested in the same manner at a temperature of 75° C. (167° F.).

(*c*) *Porcelain for spark plugs.*—In addition to the test prescribed in Paragraph (*a*), not less than 10 specimens shall be tested to determine the effect of high temperatures on the dielectric strength. The specimens shall be placed in an electrically heated oven the temperature of which can be raised at a constant rate to 600° C. (1112° F.). A given voltage shall be applied and maintained constant and the temperature raised at any constant rate such that the porcelain is always practically at the temperature of the air. The temperature shall be raised until puncture occurs.

(*d*) Whenever a puncture occurs at a point other than the minimum section of the specimen in any of the tests prescribed above, that result shall be discarded.

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[1] See p. 711.

Report. 19. The report shall include the following:

(*a*) A statement of the purpose for which the porcelain is intended and the kind of tests which were made.

(*b*) The thickness of the specimen at the bottom of the groove.

(*c*) The voltage at puncture for each of the test specimens together with the average, maximum and mimimum volts per mil or per millimeter of thickness.

V. RESISTANCE TO THERMAL CHANGE.

(*A*) *Porcelain for Transmission Line Insulators.*

Apparatus. 20. The apparatus shall consist of a hot water bath maintained at a temperature of 100° C. (212° F.) and an ice water bath maintained at 0° C. (32° F.).

Specimens. 21. The test specimens shall be as shown in Fig. 1.

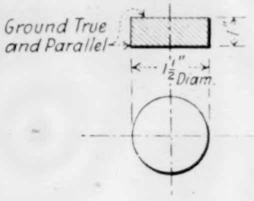

FIG. 7.

Method. 22. (*a*) The test specimen shall be immersed in the ice water bath for ten minutes and then transferred as quickly as possible to the hot water bath, and allowed to remain there for ten minutes. The specimen shall be transferred back to the cold water and the cycles continued until the specimen breaks.

(*b*) Not less than five specimens shall be tested.

Report. 23. Report the number of cycles necessary to cause fracture of each test specimen.

(*B*) *Porcelain for Spark Plugs and Heating Devices.*

Apparatus. 24. A furnace in which a temperature of 900° C. (1652° F.) can be obtained and any suitable testing machine for determining the transverse strength of small beams may be used.

Specimens. 25. The specimens shall be as shown in Fig. 3.

Method. 26. (*a*) One-half of not less than 12 specimens shall be taken and placed in the furnace. The rate of heating shall be so adjusted that the temperature reaches 900° C. (1652° F.) in two hours. The furnace shall then be allowed to cool at such a rate that room temperature is reached in four hours.

(*b*) All specimens for transverse strength shall be tested by placing them on supports 6 in. apart and loading them at the center.

Report. 27. The report shall include the following:

(*a*) The load in pounds or kilograms required to break each specimen not subjected to heat treatment, together with the average.

(*b*) The load required to break each specimen that was subjected to heat treatment, together with the average.

(*c*) The percentage loss of strength due to heat treatment calculated from the two averages.

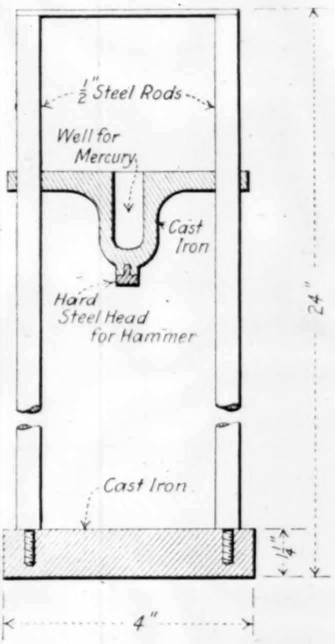

FIG. 8.

VI. POROSITY.

(*A*) *Moisture Absorption.*

28. Any good chemical balance, a beaker of distilled water at normal room temperature of about 20° C. (68° F.) and an oven of any standard made capable of maintaining a uniform temperature at the desired point within ± 5° C. shall be provided. **Apparatus.**

29. A single piece of porcelain shall be used weighing from 30 to 50 g. and with at least 50 per cent of the surface newly fractured. **Specimens.**

30. The specimen shall be dried for 24 hours at 120° C. (248° F.), cooled in a desiccator and weighed. The specimen shall then be totally submerged in the distilled water at room temperature (about 20° C.) and allowed to remain submerged for 100 hours. The water shall be boiled for approximately one hour during the first, twenty- **Method.**

fifth, forty-ninth and seventy-third hours. The specimen shall be removed at the end of the 100-hour period, the surface moisture carefully dried off with a clean, dry cloth and the specimen weighed.

Report. 31. The report shall include the following:

(*a*) The original weight of the specimen;

(*b*) The dry weight of the specimen;

(*c*) The dry weight of the specimen after immersion for 100 hours;

(*d*) The percentage of moisture content in each specimen as received and the percentage of moisture absorbed during 100 hours, taking the dry weight as 100 per cent, and the average where more than one specimen is tested.

(*B*) *Penetration of Dye.*

Apparatus. 32. A closed receptacle containing an alcoholic dye solution and a pump with which a pressure up to 600 lb. per sq. in. can be maintained in the receptable shall be provided.

Specimen. 33. A single specimen of porcelain shall be used, weighing at least 30 g. and with at least 50 per cent of the surface newly fractured. This specimen may be taken from any piece of finished ware, but if the piece varies materially in thickness (as, for example, in a transmission line insulator), a specimen shall be taken from both the thinnest and the thickest portions.

Method. 34. The specimen shall be immersed for two hours in a saturated methol alcoholic solution of eosin or fuchsine at a pressure of not less than 200 lb. per sq. in. nor more than 600 lb. per sq. in. at a room temperature of about 20° C. (68° F.).

Report. 35. The report shall include a statement of the maximum depth of penetration of the dye toward the interior of the specimen from the fractured surface exposed to the solution. (Lines of penetration along obvious cracks caused by possible fracturing are to be disregarded.)

TENTATIVE METHODS OF TESTING TRANSFORMER AND SWITCH OILS.[1]

Serial Designation: D 117 – 21 T.

These methods are issued under the fixed designation D 117; the final number indicates the year of original issue or in case of revision, the year of last revision.

Issued, 1921.

Material Covered.

1. These tests are intended for hydrocarbon oils used in transformers, switches and other electrical apparatus as an insulating and cooling medium.

I. PHYSICAL AND CHEMICAL TESTS.

Physical and Chemical Tests.

2. Each of the following tests shall be made in accordance with the method of test applicable, of the American Society for Testing Materials, as indicated:

(*a*) Viscosity: Standard Methods of Testing Lubricants (Specific Gravity, Free Acid, Carbon Residue, Viscosity (Serial Designation: D 47).[2]

(*b*) Flash Point: Tentative Method of Test for Flash and Fire Points by means of Open Cup (Serial Designation: D 92 – 21 T).[3]

(*c*) Fire Point: Tentative Method of Test for Flash and Fire Points by Means of Open Cup (Serial Designation: D 92 – 21 T).[3]

(*d*) Pour Point: Tentative Method of Test for Cloud and Pour Points of Petroleum Products (Serial Designation: D 97 – 21 T).[4]

(*e*) Acidity: Standard Methods of Testing Lubricants (Specific Gravity, Free Acid, Carbon Residue, Viscosity (Serial Designation: D 47).[2]

(*f*) Sulfur: Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Petroleum Products (Serial Designation: D 89 – 21 T).[5]

Note.—The importance of a sludging test is recognized but none of the methods in more general use at the present time is considered to be sufficiently satisfactory to warrant consideration for standardization purposes. Certain new methods are being investigated and it is expected that a satisfactory method can be proposed in 1922.

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[1] Criticisms of these Tentative Methods are solicited and should be directed preferably before January 1, 1922, to Mr. H. S. Vassar, Secretary of Committee D-9 on Electrical Insulating Materials, 102 River St., Newark, N. J.

[2] 1921 Book of A.S.T.M. Standards.

[3] See p. 651.

[4] See p. 674.

[5] See p. 643.

II. DIELECTRIC STRENGTH.

Sampling from Shipping Containers.

3. (*a*) The dielectric strength of this class of material is very greatly affected by the most minute traces of certain impurities, particularly moisture. It is therefore exceedingly important that the samples be handled with the utmost care to avoid contamination. Therefore the following procedure and precautions shall be observed in obtaining and transporting samples of the oil to be tested.

(*b*) When not in use all sampling apparatus shall be kept in a hot, dry cabinet or compartment at a temperature not less than 38° C. (100° F.). Containers for samples shall be kept unstoppered but shall be closed immediately after they are taken out of the hot compartment preparatory to being filled.

(*c*) When not in actual use, thiefs shall be kept at all times in a vertical position in a rack having a suitable drainage receptacle at the base.

When sampling a shipment of oil enough thiefs should be provided to insure complete drainage of each thief before it is used a second time. For obtaining only a few samples, two or three thiefs are enough, but for sampling a car lot six or more are desirable.

(*d*) Samples shall not be drawn from containers out of doors and not indoors until the oil is at least as warm as the surrounding air. Transformer oils are not hygroscopic but cold oil may condense enough moisture on the surface from a humid atmosphere to seriously affect its insulating properties.

(*e*) The packages shall be lined up and numbered, bungs up. The stoppers shall be unsealed and removed and laid with the oily side up beside the bung holes. The unstoppered sampling receptacle shall be placed on the opposite side of the bung holes. The top hole of the thief shall be closed with the thumb, the thief quickly thrust to the bottom of the container and the thumb removed. When the thief is filled the thumb shall be replaced, the thief quickly withdrawn and the contents allowed to flow into the sampling receptacle. The lower holes shall not be closed with the finger of the other hand. The free hand shall be used to guide the stream of oil by touching the thief only as necessary. The oil shall not be allowed to flow over the hand or fingers. When the sampling receptacle is filled it shall be closed quickly and the bung replaced in the container and tightened. The sampling receptacle shall be taken under cover to the testing laboratory as quickly as feasible.

(*f*) After using, thoroughly clean all thiefs and sampling receptacles using special care that no lint or other fibrous material remains in or on them.

(*g*) The thief shall be suitable for reaching the bottom of the container and the sample shall be taken with the thief not more than about $\frac{1}{8}$ in. from the bottom.

NOTE.—A convenient and simple thief for use with 50-gal. drum containers may be made of tin as follows: Length 28 in. and diameter $1\frac{1}{4}$ in., with cone-shaped caps over the ends and having openings at the ends $\frac{3}{8}$ in. in diameter. Two rings soldered to opposite sides of the thief at one end will be found convenient for holding the thief by slipping two fingers through them, leaving the thumb free to close the opening. For tank cars the standard thief employing a trap at the bottom is most convenient.

(*h*) It is recommended that one quart of oil be taken as a sample and that at least one sample be taken from a tank car of oil. If the oil is in drums or other metal containers, one sample per 500 gal. is recommended.

Sampling from Transformers, Switches, etc.

4. When taking samples of oil from transformers, switches and other apparatus where a thief cannot be used, the procedure outlined in Section 3 shall be followed as far as practicable. In addition, care shall be taken to procure a sample which fairly represents the oil at the bottom of the tank. Sufficient oil should therefore be drawn off before the sample is taken to insure that the sample will not be that which was stored in the sampling pipe. For this reason the valve and the drain pipe should be sufficiently small to be emptied with convenience and yet sufficiently large to give an even flow of oil and avoid clogging by sediment. A $\frac{1}{4}$-in. pipe and valve is recommended. This of course may be separate from the drainage pipe and valve or may be connected to the drainage valve by means of a suitable reducer.

Apparatus.

5. (*a*) The apparatus shall be as described in Section 14 of the Tentative Methods of Testing Molded Insulating Materials (Serial Designation: D 48-21 T) of the American Society for Testing Materials.[1]

(*b*) The sample shall be tested between polished brass or copper circular disk electrodes one inch in diameter and having a square edge. The electrodes shall be placed with their axes horizontal and coincident, and with a gap of 0.1 in. between their adjacent faces.

NOTE.—Other forms of test gap now in common use are: (1) metal disks $\frac{1}{2}$ in. in diameter spaced 0.2 in. apart with their axes horizontal and (2) spheres $\frac{1}{2}$ in. in diameter spaced 0.15 in. apart and with the axis of the gap vertical. If the values of dielectric strength observed with gaps of these two types are multiplied by the factors 0.55 and 0.50, respectively, the results will give the dielectric strength of the material in the standard gap described above: namely, 1-in. disks spaced 0.1 in. apart. These results were obtained from the extensive series of experiments described in Appendix[2] I to the Report of Committee D-9 of the American Society for Testing Materials in 1921.

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[1] See p. 711.

[2] See p. 397.

Procedure. 6. (*a*) The electrodes and the containing vessel shall be wiped clean and thoroughly rinsed with oil-free, dry gasoline until they are entirely free from fibers. They shall then be rinsed at least once with a sample of the oil to be tested. The temperature of the gap and of the sample shall be between 20 and 30° C. (68 and 86° F.) The gap shall be filled with oil to a height of not less than 20 mm. (0.787 in.) above the top of the disks. Voltage shall be applied and increased uniformly at a rate of approximately 3000 volts (rms.) per second until breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

(*b*) Provision shall be made for opening the primary circuit as promptly as possible after breakdown has occurred in order to prevent unnecessary carbonization of the oil. After each puncture the testing vessel shall be jarred to loosen particles of carbon adhering to the electrodes and the oil gently agitated but not with sufficient violence to introduce air bubbles.

(*c*) Five breakdowns shall be made on each filling after which the vessel shall be emptied and refilled with fresh oil from the original sample. The test shall be continued until the mean of the averages of at least three fillings are consistent within 10 per cent.

Report. 7. The report shall include the following:

(*a*) The volts (rms. value) at each "shot," the average voltage for each of the three or more fillings and the grand average;

(*b*) The approximate temperature of the oil at the time of the test.

NOTE.—A precision of about 3 per cent may be reasonably expected in 15 tests distributed among three consistent fillings taken in succession. But if the length of the gap is readjusted and possibilities of contamination exist, the precision may be only 6 or 7 per cent. Differences as great as 10 or 12 per cent may occur between different laboratories even where the work is carefully done. (See Appendix I to Report of Committee D-9 of the American Society for Testing Materials in 1921.)

TENTATIVE GENERAL SPECIFICATIONS
FOR
4-ONE BOXES AND SIMILAR TYPE BOXES.[1]

Serial Designation: D 118 - 21 T.

These specifications are issued under the fixed designation D 118; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered.

1. These specifications cover three styles of 4-One and similar type boxes as follows:

(*a*) General form.
(*b*) Boxes with wedglock ends.
(*c*) Boxes with detached tops.

GENERAL FORM.

2. (*a*) The boxes knocked down shall consist of separate sections forming top, sides, and bottom, connected only by continuous steel binding wires; and of separate ends.

(*b*) Each of the separate sections forming the sides, top and bottom shall consist of cleats, thin boards, wire and staples.

(*c*) The separate sections shall be separated such a distance from each other that the wires shall be in tension at the corners when the sections are folded.

I. GROUPING OF WOODS.

Grouping of Woods.

3. For the purposes of these specifications, box lumber shall be classed into four groups as follows:

GROUP I.

Alpine fir
Aspen
Balsam fir
Basswood
Buckeye
Butternut
Cedar
Chestnut
Cottonwood
Cucumber
Cypress
Jack pine
Lodgepole pine
Magnolia
Noble fir
Norway pine
Redwood
Spruce
Sugar pine
Western (yellow) pine
White fir
White pine
Willow
Yellow poplar

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. T. R. C. Wilson, Secretary of Committee D-10 on Shipping Containers, Forest Products Laboratory, Madison, Wis.

GROUP II.

Douglas fir
Hemlock
Larch (tamarack)
Southern yellow pine
Virginia and Carolina pine

GROUP III.

Black ash
Black gum
Maple, soft or silver
Pumpkin ash
Red gum
Red gum sapwood (commonly called sap gum)
Sycamore
Tupelo
White Elm

GROUP IV.

Beech
Birch
Hackberry
Hickory
Maple, hard
Oak
Rock elm
White ash

II. MATERIALS.

Cleats. 4. (*a*) Each cleat shall be sound, free from knots and from cross grain which runs across it within a distance equal to one-half its length.

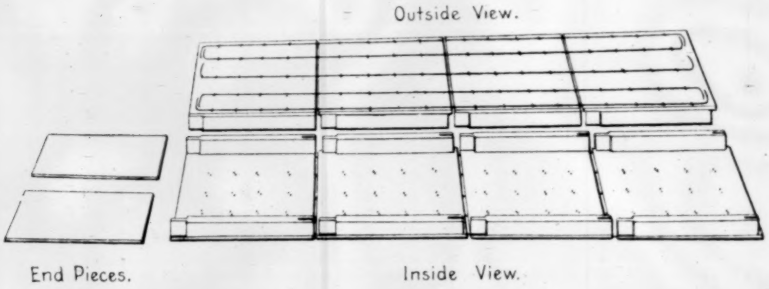

FIG. 1.

(*b*) Cleats shall be not less than $\frac{3}{4}$ in. thick (parallel to the length of the box) and not less than $\frac{7}{8}$ in. in width.

Thin Boards. 5. (*a*) The thin boards shall be sound (free from decay and dote), well seasoned and cut so that adjacent faces of boxes will be at right angles to each other. All defects that would materially lessen the strength, expose the contents of the box to damage, or interfere with the proper assembly of the box shall be eliminated.

(*b*) When the thickness of thin boards as specified is less than $\frac{3}{16}$ in., thin boards made of woods of Groups III and IV may be $\frac{1}{32}$ in. less than the specified thickness, except that the minimum thickness of thin boards of any kind of wood shall be $\frac{1}{8}$ in.

(*c*) The variation in thickness of thin boards below the thickness specified shall be not more than $\frac{1}{8}$ of the thickness of the thin board and this variation below the specified thickness shall not extend over more than 10 per cent of the face of that particular board.

(*d*) Thin boards less than $2\frac{1}{2}$ in. in width at either end shall not be used.

Binding Wire. 6. The binding wires shall be annealed steel wire of not less than No. 16 gage.

Staples. 7. (*a*) The staples on end wires shall be not less than No. 16 gage by $1\frac{1}{8}$ in. long.

(*b*) Staples on intermediate wires shall be not less than No. 18 gage by $\frac{7}{16}$ in. long.

III. ASSEMBLING.

Driving of Staples. 8. (*a*) The staples on end wires shall be driven home astride the binding wires, through the thin boards into the cleats, and anchored in the cleats.

(*b*) The staples on intermediate wires shall be driven astride the binding wires, through the thin boards and firmly clinched.

(*c*) The space between staples shall be the average distance between centers of staples astride each binding wire in each section and this space shall be not more than $2\frac{1}{2}$ in. except as specified in Paragraph (*d*).

(*d*) When cleats are made of woods of Groups III and IV, the space between staples may be $\frac{1}{4}$ in. greater than that specified.

(*e*) There shall be not less than two staples driven astride each wire and into each thin board.

(*f*) The staples nearest the corners shall be not more than $1\frac{3}{4}$ in. from the corner to which it is adjacent.

Fastening of Ends. 9. Each end of the box shall be securely fastened on the inside of the side cleats with staples not less than No. 16 gage by $\frac{13}{16}$ in. long, or with cement-coated nails of not less than two-penny size. There shall be no space exceeding $2\frac{1}{2}$ in. on any side cleat into which no staple or nail holding the end in place has been driven and there shall be a staple or nail within $1\frac{1}{2}$ in. of each end of each side cleat. Staples or nails shall be driven home.

Box Corners. 10. At each corner one section shall overlap its adjacent section at right angles and the wire shall be in tension, giving a square, tight corner.

Fastening Cover. 11. The cover shall be closed tightly and the ends of each binding wire twisted tightly together. The twisted portion of each wire shall be not less than $\frac{1}{2}$ in. long. The rough ends of the wires shall be removed and the twisted portion driven flat against the side, parallel with the binding wire.

Use of Heavier Material. 12. Nothing herein contained shall be construed as prohibiting the use of boxes constructed of thicker thin-boards, additional or heavier wires, heavier cleats, longer staples, or with closer spacing of staples.

BOXES WITH WEDGLOCK ENDS.

Boxes with Wedglock Ends. 13. These boxes shall consist of sides, top and bottom and one end made in accordance with Sections 2 to 12, inclusive, and of one wedglock end.

Wedglock Ends. 14. The wedglock ends shall consist of the following:

(*a*) One or more thin boards whose thickness is not less than that of the thin boards in the other portions of the box and whose combined width is $\frac{1}{8}$ in. less than the shortest distance between the top and bottom cleats of the box and whose length is the same as the inside width of the box less the width of one of the side cleats.

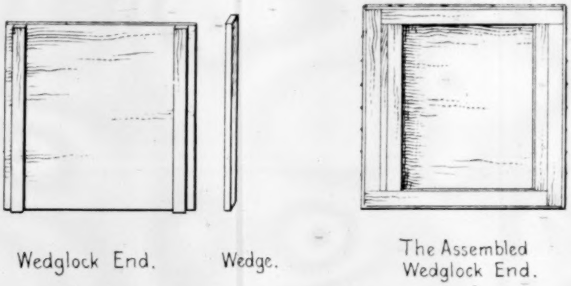

FIG. 2.—Wedglock End.

(*b*) Two battens of the same thickness and width as the cleats in the box and whose length is $\frac{1}{8}$ in. less than the shortest distance between the top and bottom cleats.

(*c*) One wedge of the same thickness and length as the battens and whose width is one-half that of the battens.

Assembling of End. 15. The battens shall be attached across the grain of the thin boards, one batten its own width from one end and the other batten half its width from the other end of the thin-boards, with staples not less than No. 16 gage by $\frac{13}{16}$ in. long or with nails not less than two-penny in size. There shall be no space exceeding 2 in. on any batten into which no staple or nail holding the thin-boards to the batten has been driven and there shall be a staple or nail within $1\frac{1}{2}$ in. of each end of each batten. Staples or nails shall be driven home.

NOTE.—In making up the box, the wedglock end is left out so that the box may be filled from the end. The other end of the box is fastened in place and the box made up as specified in Sections 9 to 11. The wedglock end is not fastened in place until the box is closed.

Boxes with wedglock ends are closed as follows: The wedglock end is inserted. The wedge is inserted. The batten that rests against the wedge is fastened to the wedge with one four-penny nail driven through the middle of the batten into the wedge. The other batten that rests against the cleat is fastened to that cleat with four-penny nails driven through the batten into the cleat. Nail centers shall be not more than 4 in. apart and there shall be a nail within at least 2 in. of each end of this batten.

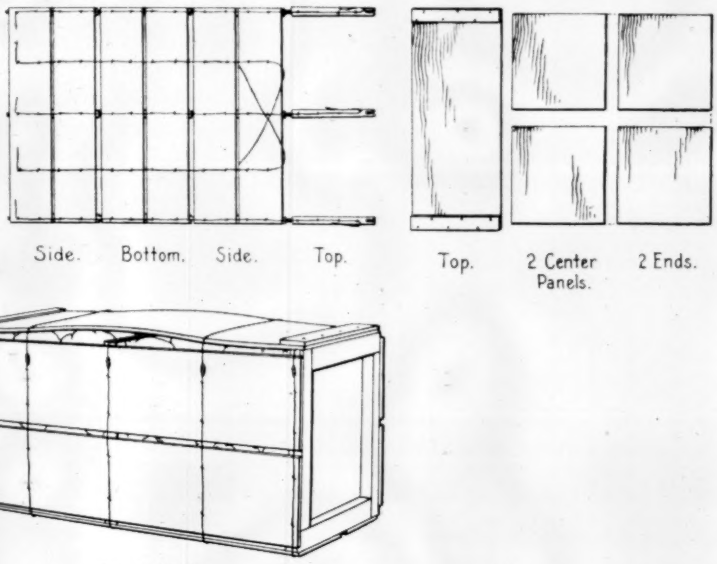

FIG. 3.

BOXES WITH DETACHED TOPS.

Boxes with Detached Tops.

16. These boxes shall consist of sides, bottom and ends made in accordance with Sections 2 to 12, inclusive, and a detached top.

Detached Top.

17. The detached top shall consist of thin boards assembled as shown in Fig. 3.

Assembling.

18. In assembling the box, the top cleats to which the binding wires have been stapled shall be put in position on the side cleats and the ends of each wire stapled to the cleats twisted tightly together.

The detached top shall be nailed to the end cleats with cement-coated box nails spaced not more than $2\frac{1}{2}$ in. apart. The wires not stapled to the cleats shall be brought over the detached top and the ends of each wire twisted tightly together.

TENTATIVE SPECIFICATIONS

FOR

INSULATED WIRE AND CABLE: 30-PER-CENT HEVEA RUBBER.[1]

Serial Designation: D 27 – 21 T.

These specifications are issued under the fixed designation D 27; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1916; REVISED, 1921.

Scope. 1. These specifications cover conductors, rubber insulation, rubber-filled cloth tape and braid. The design and factor of safety depend upon the service conditions and shall be at the option of the purchaser.

(*A*) CONDUCTOR.

I. MANUFACTURE.

Material. 2. The conductor shall be of soft annealed copper, properly tinned, and have the properties and characteristics herein required.

Strand. 3. Each individual wire of a stranded conductor shall be considered separately and shall be designated as a strand.

Shape. 4. Each solid conductor and each strand shall be round and reasonably free from imperfections.

Stranding. 5. The stranding shall be concentric and unless otherwise specified shall conform to either Table I or Table II.

Density. 6. For the purpose of calculating weights, cross-sections, etc., in conductivity determinations, the density of copper shall be taken as 8.89. (See Appendix I.)

II. PERMISSIBLE VARIATIONS IN DIMENSIONS.

Diameter and Area. 7. (*a*) *Permissible Variation.*—When the diameter of solid conductors and strands is specified, the permissible variation from the specified value shall not exceed 1 per cent under or 2 per cent over for wire 0.02 in. in diameter and larger, and 0.1 mil under for wire less than 0.02 in. in diameter.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

TABLE I.—STANDARD STRANDING FOR CABLE.
(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.)

Size (See Note 1).		Number of Wires (See Note 2).	
	Sq. mm.	A Bare, insulated or weatherproof cables for aerial use.	B Insulated cables for other than aerial use.
2.0 cir. in	1013	91	127
1.5 "	760	61	91
1.0 "	507	61	61
0.6 "	304	37	61
0.5 "	253	37	37
0.4 "	203	19	37
0000 A.w.g	107	19 or 7 (See note 3)	19
00 "	67.4	7	19
2 "	33.6	7	7
7 and smaller	10.5	...	7

NOTE 1.—For intermediate sizes, use stranding for next larger size. A circular inch equals 1 000 000 circular mils.

NOTE 2.—Conductors of 0000 A.w.g. and smaller are often made solid and this table of stranding should not be interpreted as excluding this practice.

NOTE 3.—Class A cables, sizes 0000 and 000 A.w.g., are usually made of 7 strands when bare and 19 strands when insulated or weather proof.

TABLE II.—PROPOSED STANDARD STRANDING FOR CABLES.[1]
(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.)

Strands.			Total Nominal Cross-Section, circular mils.	Total Diameter, in.
Number and Size. (See Note.)	Individual Strands.			
	Nominal diameter, mils.	Nominal Circular mils.		
127 No. 8	128.5	16 510	2 097 000	1.671
127 No. 9	114.4	13 090	1 662 000	1.487
91 No. 8	128.5	16 510	1 502 000	1.414
91 No. 9	114.4	13 090	1 191 000	1.258
61 No. 8	128.5	16 510	1 007 000	1.157
61 - 121 mils	121.0	14 641	893 100	1.089
61 No. 9	114.4	13 090	798 500	1.030
61 - 107 mils	107.0	11 449	698 400	0.963
61 No. 10	101.9	10 380	633 200	0.917
37 - 116 mils	116.0	13 456	497 900	0.812
37 No. 10	101.9	10 380	384 100	0.713
37 - 97 mils	97.0	9 409	348 100	0.679
37 No. 11	90.74	8 234	304 700	0.635
19 No. 9	114.4	13 090	248 700	0.572
19 - 107 mils	107.0	11 449	217 500	0.535
19 No. 11	90.74	8 234	156 400	0.454
19 No. 12	80.81	6 530	124 100	0.404
19 No. 13	71.96	5 178	98 380	0.360
19 No. 14	64.08	4 107	78 030	0.320
7 No. 10	101.9	10 380	72 660	0.306
7 No. 11	90.74	8 234	57 640	0.272
7 No. 12	80.81	6 530	45 710	0.242
7 No. 14	64.08	4 107	28 750	0.192
7 No. 16	50.82	2 583	18 080	0.152
7 No. 18	40.30	1 624	11 370	0.121
7 No. 20	31.96	1 022	7 154	0.096
7 No. 22	25.35	642.4	4 497	0.076
7 No. 24	20.10	404.0	2 828	0.060

NOTE.—Nominal diameters and circular mils of the individual strands are taken from Table VI, *Circular No. 31* of the Bureau of Standards.

Sizes are expressed as A.w.g. gage numbers except where diameters are given in mils.

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[1] This table is proposed by the A. I. E. E., but the following note appears at the head of the table: "This table is offered for consideration, but will not be recommended for final adoption until ratified by other societies interested."

NOTE.—These limits differ from those in the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (Serial Designation: B 33) of the American Society for Testing Materials[1] because of the additional manipulation to which the wire is subjected subsequent to the stage where Specifications B 33 apply.

When the area of cross-section of cables is specified, the permissible variation shall not exceed 1 per cent under the specified value.

(*b*) *Method of Gaging Diameter.*—When wire is submitted in coils, each coil shall be gaged in three places, one near each end and one approximately at the middle. When wire is submitted on spools or reels, approximately 12 ft. of the wire shall be reeled off and the wire then gaged in six places between the second foot and the twelfth foot from the end.

(*c*) *Calculation of Area.*—The area of cross-section of wire shall be calculated from the average of the measurements of the diameter made in accordance with Paragraph (*b*). The area of cross-section of cable shall be considered to be the sum of the cross-sectional areas of its component wires, when laid out straight and measured perpendicular to their axes.

TABLE III.—TENSILE PROPERTIES OF CONDUCTORS.

Diameter, in.	Maximum Tensile Strength, lb. per sq. in.	Minimum Elongation in 10 in., per cent.
0.460 to 0.290	36,000	30
0.289 " 0.103	37,000	25
0.102 " 0.021	38,500	20
0.020 " 0.012	39,000	15
0.011 " 0.003	40,000	10

(*d*) *Rejection.*—A coil or reel shall be rejected if the average diameter obtained from the measurements made in accordance with Paragraph (*b*), or the area calculated in accordance with Paragraph (*c*), is not within the limits specified in Paragraph (*a*).

A coil or reel shall be rejected if any individual measurement of diameter or of area of cross-section is not within twice the limits of Paragraph (*a*).

III. PHYSICAL PROPERTIES AND TESTS.

Tensile Properties.

8. (*a*) Each solid conductor and each strand previous to stranding shall be so drawn and annealed that after tinning it shall conform to the values in Table III.

After stranding, the tensile strength of each strand shall not exceed that specified in Table III by more than 5 per cent and the minimum elongation in 10 in. shall not be less than that specified in Table III by more than 5 per cent.

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[1] 1921 Book of A.S.T.M. Standards.

(*b*) For nominal diameters between listed sizes the requirements shall be those of the next larger sizes indicated in Table III.

Tension Tests.

9. (*a*) *Method of Test.*—Tension tests shall be made on fair samples and the elongation shall be determined as the permanent increase in length, due to the breaking of the wire in tension, measured between bench marks originally 10 in. apart. The specimen shall break between the bench marks and not closer than 1 in. to either mark.

(*b*) *Number of Tests.*—Samples shall be taken in accordance with Section 18.

(*c*) *Retests and Rejections.*—If upon testing a sample from a coil, reel or spool of wire, the results are found to be above the stated value for tensile strength or below the stated value for elongation, tests upon two additional samples will be made and the average of the three tests shall determine acceptance or rejection.

Conductivity

10. The conductivity of the conductors after tinning shall be not less than the following values:

DIAMETER, IN.	CONDUCTIVITY, PER CENT.
0.460 to 0.290	97.65
0.289 " 0.103	97.15
0.102 " 0.021	96.15
0.020 " 0.012	94.15
0.011 " 0.003	93.15

NOTE.—The above values for conductivity are based on the International Standard for Annealed Copper Wire. (See Appendix I.)

Tinning Test.

11. (*a*) The continuity of the tin coating of each sample before stranding or insulating shall be determined by the Sodium Polysulfide test which shall be made in accordance with the requirements of Sections 4 to 10 of the Standard Specifications for Tinned Soft or Annealed Copper Wire for Rubber Insulation (Serial Designation: B 33) of the American Society for Testing Materials.[1]

(*b*) *Number of Tests.*—Samples shall be taken in accordance with Section 18.

(*c*) *Retests and Rejections.*—If the specimens tested in accordance with Paragraph (*a*) shows any signs of blackening, two more specimens shall be tested. If one of these two additional specimens shows any blackening, that coil or reel shall be rejected. If both specimens are free from any signs of blackening, the coil or reel shall be accepted. If more than 10 per cent of the samples in the entire order fail, all of the wire shall be rejected. If 10 per cent or less of the samples in the entire lot fail, each coil, reel or length may be tested and accepted or rejected upon the results of the individual tests.

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[1] 1921 Book of A.S.T.M. Standards.

(*B*) INSULATION.

Workmanship.

12. (*a*) The insulation shall be a properly vulcanized rubber compound, homogeneous in character, tough, elastic and applied concentrically about the conductor and shall fit tightly thereto. When the insulation is applied in more than one layer, adjacent layers shall vulcanize into a homogeneous mass. Tape may be applied over the insulation before vulcanizing but such tape, if it does not meet the tape specifications given in Sections 24–27 inclusive, shall be additional to that required.

(*b*) If exigencies of manufacture require repairs or joints in the insulation, the work shall be done in such manner that the repaired part or joint, and all parts affected by it, shall be as strong and durable electrically, as the remainder of the insulation.

TABLE IV.—THICKNESS OF INSULATION.
(Thickness in sixty-fourths of an inch.)
(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.)

Size of Conductor.		Working Pressure, Volts Alternating.										
A.w.g. or Cir. Mils.	Sq. mm.	600 or less	1,500	2,500	3,500	5,000	6.000	7,000	8.000	9,000	10,000	11,000
14 - 8	2.08 - 8.37	3	6	8	10	12	14	16	18	20	22	24
7 - 2	10.6 - 33.6	4	7	9	10	12	14	16	18	20	22	24
1 - 0000	42.4 - 107	5	8	10	10	12	14	16	18	20	22	24
250,000 - 500,000 C.M.	127 - 253	6	9	10	11	12	14	16	18	20	22	24
550,000 - 1,000,000 C.M.	279 - 507	7	10	10	12	12	14	16	18	20	22	24
1,250,000 - 2,000,000 C.M.	633 - 1013	8	10	10	12	14	16	18	18	20	22	24

NOTE.—In multiple conductor cables, the thickness of insulation on each conductor shall be based on the highest r. m. s. voltage between the conductor and the outside of this insulation.

The above table is based upon alternating voltages of commercial frequencies. For voltages over 600, the insulation thickness for direct-current cable has not been established. For intermediate sizes the insulation thickness should be the same as for the next larger sizes.

IV. THICKNESS.

Thickness.

13. (*a*) The thickness of the insulation shall conform to Table IV.

(*b*) *Permissible Variation.*—The average thickness of the insulation shall be not less than that specified. The thickness of the insulation at the thinnest part shall be not less than 90 per cent of the specified thickness, but in no case shall it be more than 0.03125 ($\frac{1}{32}$) in. less than the specified thickness.

(*c*) *Method of Measuring.*—The average thickness shall be taken as one-half the difference between the mean of the maximum and minimum diameters measured at any one point, and the average diameter of the conductor measured at the same point. The minimum thickness shall be taken as the difference between a measurement made over the conductor plus the thinnest wall, and the diameter of the conductor. (The first measurement is made by "slicing off" the heavier side of the insulation.)

The measurements may be made with any type of micrometer, reading to at least 0.001 in., which is suitable for measurements of this character.

In the case of multiple-conductor cable, the measurements shall be made on the individual wires before being cabled.

(*d*) *Number of Measurements.*—When the lot of wire to be inspected consists of two coils or reels or less, at least one determination of the thickness shall be made on each coil or reel. When the lot consists of more than two coils or reels and less than 20 coils or reels, at least one determination of the thickness shall be made on each of the two coils or reels taken at random. If the lot consists of 20 coils or reels or over, at least one determination of the thickness shall be made on each lot of not less than 10 per cent of the total number of coils or reels.

(*e*) *Rejection.*—If the thickness of any coil or reel is found to be less than the prescribed value, that coil or reel shall be rejected and a thickness measurement on each of the remaining coils or reels shall be made.

V. CHEMICAL PROPERTIES AND TESTS.

Composition of Compound.

14. (*a*) *Composition.*—The insulation shall contain exclusively Hevea rubber which has not been previously used, waxy hydrocarbons consisting of ceresine or refined solid paraffin, sufficient sulfur to properly vulcanize, and fillers which are entirely inorganic mineral matter containing no red lead, carbon or bitumen.

(*b*) *Requirements.*—The vulcanized compound shall conform on analysis to the following requirements expressed as percentages, by weight, of the whole sample:

	MAXIMUM.	MINIMUM.
Rubber	33	30
Waxy hydrocarbons	4	..
Free sulfur	0.7	..

Results shall be taken between the limits given in proportion to the percentage by weight of the rubber found.

The limits allowed for 30-per-cent rubber compound shall be as follows:

	MAXIMUM.	MINIMUM.
Saponifiable acetone extract	1.35	0.55
Unsaponifiable resins	0.45	....
Chloroform extract	0.90	....
Alcoholic potash extract	0.55	....
Total sulfur (see note)	2.10	....
Specific gravity	....	1.75

The limits allowed for 33-per-cent rubber compound shall be as follows:

	Maximum.	Minimum.
Saponifiable acetone extract	1.50	0.60
Unsaponifiable resins	0.50	....
Chloroform extract	1.00	....
Alcoholic potash extract	0.60	....
Total sulfur (see note)	2.30	....
Specific gravity	....	1.67

The acetone solution shall not fluoresce.

The acetone extract (60 cc.) shall not be darker than a light straw color.

Hydrocarbons shall be solid, waxy and not darker than a light brown.

Chloroform extract (60 cc.) shall not be darker than a straw color.

Contamination of the compound, such as by the use of impregnated tapes, will not excuse the manufacturer from conforming to these specifications.

(*c*) The compound shall be analyzed by the procedure recommended by the Joint Rubber Insulation Committee. (See Appendix II.)

Note.—The limit on total sulfur may be omitted at the option of the purchaser.

(*d*) *Samples.*—Samples for chemical analysis shall be taken before the application of the braid and after the material has passed all physical and electrical tests. The purchaser may take samples in accordance with Section 18. The purchaser shall assure himself that all samples are free from contamination and change due to torch heating. Wherever practicable, samples shall be taken at a distance of at least 3 ft. from the end of the wire.

(*e*) *Retests and Rejections.*—The purchaser may make a chemical analysis on any one of the samples selected as above to determine if the compound meets the requirements of Paragraph (*b*). Failure of any one sample selected shall be sufficient cause to reject the wire which the sample represents, except in the case of failure to meet the requirements of either or both free sulfur and chloroform extract in accordance with Paragraph (*b*). In case of such failure the coil from which the sample was taken shall be rejected and two additional samples taken from the remainder of the order. The remainder of the order shall be accepted if both samples so selected shall meet the requirements for free sulfur or chloroform extract in accordance with Paragraph (*b*). The entire order shall be rejected if either sample fails to meet the requirements.

VI. PHYSICAL PROPERTIES AND TESTS.

Physical Properties.

15. The test specimen shall have the following physical properties:

Tensile strength, minimum, lb. per sq. in.	1000
Set, maximum in 2 in., in.	$\frac{3}{8}$
Elongation, minimum stretch before rupture, in.	2 to 9

Physical Tests.

16. (*a*) *Tension Test.*—A test specimen having a length of not less than 6 in., marked with bench marks 2 in. apart, shall be placed in the jaws of a testing machine (maximum distance between jaws holding the test specimen, 4 in.) and stretched at the rate of 20 in. per minute (jaw speed) until the specimen breaks. The test specimen shall break between the bench marks and the tensile strength shall be calculated upon the area of the original sample.

(*b*) *Set Test.*—A second test specimen having a length of not less than 6 in., marked with bench marks 2 in. apart, shall be placed in the jaws of a testing machine (maximum distance between jaws holding test specimen, 4 in.) and stretched at a rate of 20 in. per minute until the bench marks are 6 in. apart. After the termination of this stretch, the test specimen shall be released within 5 seconds and the set determined 1 minute after the beginning of release.

(*c*) *Elongation Test.*—After the determination of the set in accordance with Paragraph (*b*), the same specimen shall be placed in the jaws of a testing machine (maximum distance between jaws holding test specimen, 4 in.) and stretched at the rate of 20 in. per minute (jaw speed) until the specimen breaks. The test specimen shall break between the bench marks.

(*d*) *Accuracy of Machine.*—The testing machine shall be accurate within 1 per cent of the breaking load.

(*e*) *Jaws.*—The jaws of the machine shall be of an approved type.

(*f*) *Temperature.*—All physical tests shall be made at a room temperature of from 18 to 29°.5 C. (65 to 85° F.) inclusive, and the test specimen shall have been kept at the room temperature not less than 30 minutes prior to the tests.

Test Specimen.

17. (*a*) *Test Specimen.*—The test specimen may be the entire section of the insulation in the case of small wires, or in the case of a large wire, a segment of a section, cut with a sharp knife held tangentially to the conductor. The test specimen shall be as free as possible from surface incisions and imperfections.

NOTE.—The removal of the rubber insulation can be greatly accelerated and in most cases a test specimen which is an entire section can be obtained free from surface incisions and imperfections by means of metallic mercury. The mercury should be introduced at one end of the sample between the insulation and the tinned surface of the conductor, and the sample inclined on a support with the end to which the mercury is applied at the top. The separation of the rubber insulation results from the amalgamation of the tin of the conductor with the mercury. The amalgamation is assisted by first immersing and rubbing the tinning on the exposed end of the conductor in the mercury.

(*b*) *Buffing.*—In event of any irregularities on the surface of the test specimen, it shall be made smooth and of uniform thickness within 5 per cent of the original thickness by buffing, except when large strands are used, in which case the rubber sample shall be buffed sufficiently to remove all corrugations.

(*c*) *Limits.*—There shall be no limit to the cross-section of the test specimen, except as restricted by the capacity of the testing machine.

(*d*) *Calculation of Area.*—Calculation of the area of the test specimen shall be made as follows:

1. When the total cross-section of the insulation is used, the area shall be calculated as the area of the circle whose diameter is the minimum average outside diameter of the insulation minus the area of the conductor. The area of a stranded conductor shall be figured from its maximum diameter.

2. When a slice cut from the insulation by a knife held tangent to the wire is used, and the slice so cut has the cross-section of a segment of a circle, the area shall be calculated as that of the segment of a circle whose diameter is that of the insulation. The height of the segment is the wall of insulation on the side from which the slice is taken. (The values may be easily obtained from a table giving the areas of segments of a unit circle for the ratio of the height of the segment to the diameter of the circle.

3. When the cross-section of the slice is not a segment of a circle, the area shall be calculated from a direct measurement of the volume or from the specific gravity and the weight of a known length of a uniform cross-section.

4. When a portion of a sector of a circle has to be taken where the conductor is large and the insulation thin, the area shall be calculated as the thickness times the width. (This applies either to a straight test piece or one stamped out with a die, and assumes that corrugations have been removed by buffing.)

5. When a portion of a sector of a circle has to be taken where the conductor is large and the insulation thick, the area shall be calculated as the proportional part of the area of the total cross-section.

Number of Physical Test Samples.

18. (*a*) When an order calls for less than 500 ft., physical tests may be waived at the option of the purchaser.

(*b*) When an order calls for 500 ft. or more and is made into one or more coils, reels or lengths, samples shall be taken from 10 per cent of the coils, reels or lengths, but in any case at least one sample shall be taken.

Retests and Rejections. Physical Tests.

19. (*a*) *Retests.*—If a specimen fails to pass in one of the three tests prescribed in Section 15, two more specimens shall be taken from the same sample and the average of the results shall determine whether or not the sample complies with the requirements.

(*b*) *Rejections.*—When ten or more samples are selected in any inspection lot, all coils, reels or lengths shall be rejected if more than 10 per cent of the samples fail. If 10 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the results of such individual test. Where the number of samples selected in any inspection lot is less than ten, all coils, reels or lengths shall be rejected if more than 20 per cent of the samples fail. If 20 per cent or less fail, each coil, reel or length may be tested and shall be accepted or rejected upon the result of individual test.

VII. ELECTRICAL PROPERTIES AND TESTS.

Electrical Properties.

20. (*a*) *Place.*—Electrical tests on the wire and cable shall be made at the place of manufacture.

(*b*) *Requirements.*—Every coil, reel or length of wire, after vulcanization and before the application of paraffin or any covering other than tape or braid used in vulcanization, shall successfully withstand a high voltage test as specified in Table V and shall have an insulation resistance test not less than that specified in Table VI. These tests shall be made after not less than 12 hours immersion in water, and while still immersed.

TABLE V.—VALUES OF TEST POTENTIALS FOR WORKING PRESSURES UP TO 600 VOLTS. A. C.

(AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS)

SIZE, A.W.G. OR CIR. MILS.	SIZE, SQ. MM.	TEST PRESSURE, KILOVOLTS.
14–8 A.w.g..................	2.081 – 8.366	3.0
7–0000 A.w.g...............	10.55 – 107.2	3.5
250 000 C. M. and larger.........	127 and larger	4.0

For Working Pressures over 600 volts, A.C.—One kilovolt per $\frac{1}{64}$ in. of thickness (2.53 kv. per mm.) up to $\frac{10}{64}$ in. (3.96 mm.). Above $\frac{10}{64}$ in. (3.96 mm.), the test pressure shall be 10 kilovolts plus 1.5 kilovolts per $\frac{1}{64}$ in. (3.79 kv, per mm.) additional up to $\frac{30}{64}$ in. (11.89 mm.). Where the insulation thickness is $\frac{16}{64}$ in. (6.34 mm.) or over, this rule shall apply only to conductors over 26,000 cir. mils (13.2 sq. mm.) area.

High Voltage Test.

21. The test voltage shall be applied for 5 minutes. The test shall be made in accordance with the Standardization Rules of the American Institute of Electrical Engineers. (See Appendix I.)

Insulation Resistance.

22. (*a*) *Method.*—The insulation resistance test shall be made in accordance with the Standardization Rules of the American Institute of Electrical Engineers and within the range of temperature given in Table VII. (See Appendix I.)

(*b*) *Temperature Coefficient.*—The insulation resistance (megohms) shall be reduced to that at 15°.55 C. (60° F.) by multiplying by the coefficient in Table VII corresponding to the temperature at which the test is made.

TABLE VI.—INSULATION RESISTANCE, IN MEGOHM-MILES AT 15°.55 C. (60° F.).[1]

Size of Conductor.	Thickness of Insulation in sixty-fourths of an inch.																
	2	3	4	5	6	7	8	10	12	14	16	18	20	22	24	26	28
18 A.w.g.	1600	2050	2450	2800	3000	3200	3400	3750	4050	4300	4500	4700	4900	5000	5150	5300	5400
16 "	1400	1800	2150	2400	2650	2850	3050	3400	3650	3950	4150	4350	4500	4650	4800	4900	5050
14 "	..	1530	1850	2150	2350	2550	2650	3050	3350	3550	3800	3950	4100	4300	4400	4550	4650
12 "	..	1350	1600	1850	2050	2250	2400	2750	3000	3250	3400	3600	3750	3900	4050	4150	4300
10 "	..	1150	1350	1600	1800	2000	2150	2400	2650	2900	3100	3250	3400	3550	3700	3800	3900
8 "	..	850	1050	1250	1450	1650	1750	2050	2200	2400	2600	2750	2900	3050	3150	3250	3350
6 "	..	..	850	1050	1200	1350	1450	1750	1950	2100	2300	2450	2550	2700	2800	2900	3000
4 "	..	..	750	850	1000	1150	1250	1450	1650	1850	2000	2150	2250	2400	2500	2600	2700
2 "	..	..	650	750	850	950	1050	1250	1450	1600	1700	1850	1950	2100	2200	2300	2400
1 "	..	..	600	650	750	850	1000	1150	1350	1450	1600	1750	1850	1950	2050	2150	2250
0 "	..	..	..	600	700	800	950	1050	1200	1350	1500	1600	1700	1800	1900	2000	
00 "	..	..	..	550	650	750	850	950	1050	1250	1350	1500	1600	1700	1800		
000 "	..	..	..	500	600	650	750	850	1000	1150	1250	1350	1450	1550			
0 000 "	..	..	..	450	550	600	650	800	950	1050	1150	1250	1350	1450			
250 000 C.M.	..	..	..	400	475	575	625	725	875	1000	1100	1200	1275				
350 000 "	..	..	..	350	425	475	525	675	775	850	950	1050	1125				
500 000 "	..	..	..	300	375	400	475	575	675	750	850	900					
750 000 "	..	..	..	..	..	325	400	475	525	625	700	775					
1 000 000 "	..	..	..	..	..	300	325	400	475	550	625						
1 250 000 "	..	..	..	..	..	..	325	375	425	500	575						
1 500 000 "	..	..	..	..	..	..	300	325	400	475							
1 750 000 "	..	..	..	..	..	..	275	300	375	450							
2 000 000 "	..	..	..	..	..	..	200	275	325	425							

NOTE.—For intermediate sizes, use values of next larger size.

[1] This table is based on the constant 4000 in the following formula:

$R = K \log_{10} \frac{D}{d}$, where R = resistance in megohms, K = constant, D = diameter over insulation, d = diameter over conductor.

Rejections, Electrical Test.

23. Every coil, reel or length shall be rejected if it fails to comply with the electrical requirements herein specified.

(*C*) RUBBER-FILLED CLOTH TAPE.

Material.

24. The tape shall be made from cotton cloth having a weight of not less than one pound per four yards with a width of 36 in. and not less than 56 by 60 picks per in., and shall be thoroughly filled with a rubber compound.

Application.

25. The tape shall be applied helically. The maximum width and minimum overlap shall conform to the values in Table VIII.

TABLE VII.—TEMPERATURE COEFFICIENTS.

Temperature.		Coefficient.	Temperature.		Coefficient.
Deg. Fahr.	Deg. Cent.		Deg. Fahr.	Deg. Cent.	
46	7.8	0.694	61	16.1	1.026
47	8.3	0.709	62	16.7	1.053
48	8.9	0.729	63	17.2	1.081
49	9.4	0.746	64	17.8	1.109
50	10.0	0.769	65	18.3	1.138
51	10.6	0.787	66	18.9	1.169
52	11.1	0.806	67	19.4	1.200
53	11.7	0.833	68	20.0	1.231
54	12.2	0.854	69	20.6	1.264
55	12.8	0.877	70	21.1	1.297
56	13.3	0.900	71	21.7	1.331
57	13.9	0.917	72	22.2	1.366
58	14.4	0.943	73	22.8	1.402
59	15.0	0.970	74	23.3	1.438
60	15.6	1.000	75	23.9	1.477

TABLE VIII.—WIDTH AND OVERLAP FOR RUBBER-FILLED CLOTH TAPE.

Diameter Over Insulation, in.	Width, Maximum, in.	Overlap, Minimum, in.
2.00	5	$\frac{1}{2}$
1.75	$4\frac{1}{2}$	$\frac{1}{2}$
1.50	4	$\frac{1}{2}$
1.25	$3\frac{1}{2}$	$\frac{1}{2}$
1.15	$3\frac{1}{4}$	$\frac{1}{2}$
1.00	3	$\frac{1}{2}$
0.88	$2\frac{3}{4}$	$\frac{3}{8}$
0.75	$2\frac{3}{8}$	$\frac{3}{8}$
0.62	2	$\frac{3}{8}$
0.50	$1\frac{3}{4}$	$\frac{3}{8}$
0.38	$1\frac{1}{2}$	$\frac{1}{4}$
0.31	$1\frac{1}{4}$	$\frac{1}{4}$
0.25	1	$\frac{1}{4}$
0.19	$\frac{7}{8}$	$\frac{1}{8}$
0.16	$\frac{3}{4}$	$\frac{1}{8}$

Intermediate Diameters. 26. For intermediate diameters the requirements shall be those of the next smaller diameter indicated in Table VIII.

Number of Tests. 27. Samples shall be taken in accordance with Section 18 or at the option of the purchaser.

(*D*) BRAID.

Material. 28. The braid shall be closely woven from cotton thread having not less than two plys and shall be completely impregnated with an insulating waterproof compound and finished with a black insulating compound thoroughly slicked down.

Compound. 29. The compound shall be neither injuriously affected by nor have injurious effect upon the braid at a temperature of 90° C. (194° F.).

Construction. 30. (*a*) The braid shall be so constructed that the tangent of the angle between the cotton thread and the side of the wire shall be not less than 0.70. The values of the closeness constant, *k*, and the thickness of braid, *t*, shall be not less than those in Table IX.

TABLE IX.

Diameter Under Braid, in.	Minimum Closeness Constant (*k*).	Minimum Thickness of Braid (*t*), in.
$0 - \frac{7}{32}$	6	0.018
$\frac{8}{32} - \frac{14}{32}$	6	0.020
$\frac{15}{32} - \frac{20}{32}$	7	0.020
$\frac{21}{32} - \frac{23}{32}$	8	0.024
$\frac{26}{32}$ and greater	8	0.024

(*b*) The values given in Table IX shall be based upon the following formulae:

$$A = \frac{\pi p D}{a}$$

$$t = 2d$$

$$k = \frac{abt}{D} \sqrt{1+A^2}$$

in which

A = tangent of angle between the cotton thread and the side of the wire;
t = thickness of braid in inches;
k = closeness constant;
D = diameter of wire under braid in inches;

a = number of carriers;
b = number of ends per carrier
p = two times the picks per inch = number of carriers per inch;
d = average diameter of single thread of cotton per inch.

(*c*) The various quantities shall be determined as follows:

D, by a suitable micrometer after removal of the braid;

a and b, by examination of the braid;

p, on a 4 in. length of sample after wiping off the outside of the braid with chloroform;

d, by measuring 25 per cent of the total number of threads with a paper micrometer having a foot 0.4 in. in diameter, under a pressure of 50 g. The sample of braid on which the average diameter is determined can be prepared by immersing a 2 in. length of sample in chloroform in a suitable container for 5 minutes, decanting and repeating for 1 minute, and removing and drying it thoroughly by pressing it between cheese cloth.

Number of Tests. 31. Samples shall be taken in accordance with Section 18 or at the option of the purchaser.

(*E*) INSPECTION.

Inspection and Test. 32 (*a*) Inspection shall be made prior to shipment and at the place of manufacture.

(*b*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the wire or cable to permit of arrangement of inspection.

(*c*) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wire ordered, except compounding room. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications.

(*d*) The purchaser at his option may make the various tests on samples in his own laboratory or elsewhere, but such tests shall be made at the expense of the purchaser.

Rehearing. 33. Samples of rejected material shall be preserved for two weeks from date of test report. In case of dissatisfaction with the results of test, the manufacturer may make claim for a rehearing within that time. Sealed duplicate samples may be retained by the manufacturer at his option.

APPENDIX I.

EXTRACTS FROM STANDARDIZATION RULES OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

(EDITION 1921.)

CONDUCTIVITY OF COPPER.

1. The following shall be taken as normal values for standard annealed copper:

(*a*) At a temperature of 20° C. the resistance of a wire of standard annealed copper 1 m. in length and of a uniform section of 1 sq. mm. is $\frac{1}{58}$ ohm = 0.017241 ohm.

(*b*) At a temperature of 20° C. the density of standard annealed copper is 8.89 g. per cc.

(*c*) At a temperature of 20° C. the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is 0.00393 = 1/254.45 . . . per degree Centigrade.

(*d*) As a consequence, it follows from (*a*) and (*b*) that at a temperature of 20° C. the resistance of a wire of standard annealed copper of uniform section, 1 m. in length and weighing 1 g. is $\frac{1}{58} \times 8.89 =$ 0.15328 ohm.

HIGH VOLTAGE TEST.

(*a*) *Frequency.*

2. The frequency of the test voltage shall not exceed 100 cycles per second, and should approximate as closely as possible a sine wave. The source of energy should be of ample capacity.

(*b*) *Rate of Increase of Voltage.*

3. The initially-applied voltage shall not be greater than the working voltage and the rate of increase shall not be over 100 per cent in 100 seconds.

(*c*) *Multiple Conductor Cables.*

4. If a multiple conductor cable is designed for the same operating voltage between conductors and sheath, or water, as between conductors, each conductor shall be tested against the other conductors

connected together and to the sheath, or water. If the cable is designed for an operating voltage between conductors and ground different from that between conductors, the test between conductors and the sheath, or water, shall be made separately and shall be based on the normal operating voltage between conductors and sheath, or water, as prescribed for single-conductor cables.

INSULATION RESISTANCE TEST.

(*a*) *Electrification.*

5. The apparent insulation resistance should be measured after the dielectric-strength test, measuring the leakage current after a one-minute electrification, with a continuous e.m.f. of from 100 to 500 volts, the conductor being maintained negative to sheath, or water.

(*b*) *Multiple Conductor Cables.*

6. The insulation resistance of each conductor of a multiple-conductor cable shall be the insulation resistance measured from each conductor to all the other conductors in multiple with the sheath or water.

APPENDIX II.

JOINT RUBBER INSULATION COMMITTEE PROCEDURE FOR THE ANALYSIS OF RUBBER COMPOUND.

Object of the Analysis.

1. The object of this procedure of analysis is to determine whether rubber compounds comply chemically with the accompanying specification which is intended to secure compounds containing 30 per cent of the best Hevea rubber, and mineral fillers.

Outline of Procedure.

2 The general procedure is shown in Fig. 1.

General.

3. Make the analysis upon the insulation after vulcanization and, whenever possible, before the saturation of the braid. Wipe the insulation thoroughly with a damp cloth to remove any adhering material, but do not remove waxy hydrocarbons from the surface.

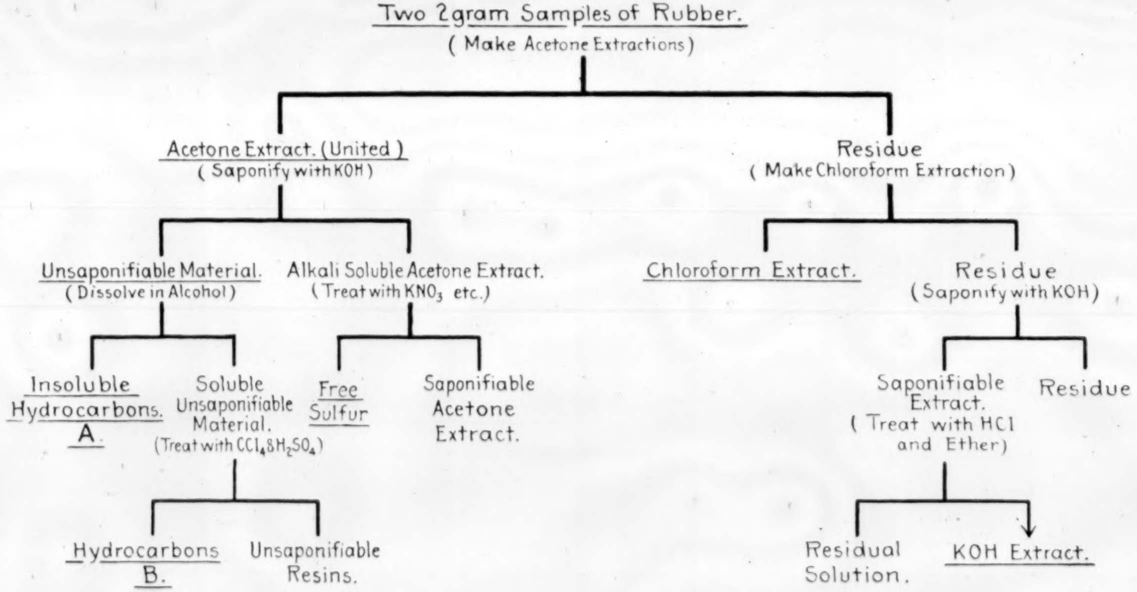
4. If, however, a saturated braided sample must be used, remove the braid and sandpaper the insulation to a depth of at least 0.005 in. and wipe with a damp cloth. In such cases report the condition of the sample.

5. Perform all determinations in duplicate and take the average value arbitrarily as the true value. Duplicate determinations must check within the limits specified.

6. Make blanks on all determinations and deduct the results accordingly.

Sample.

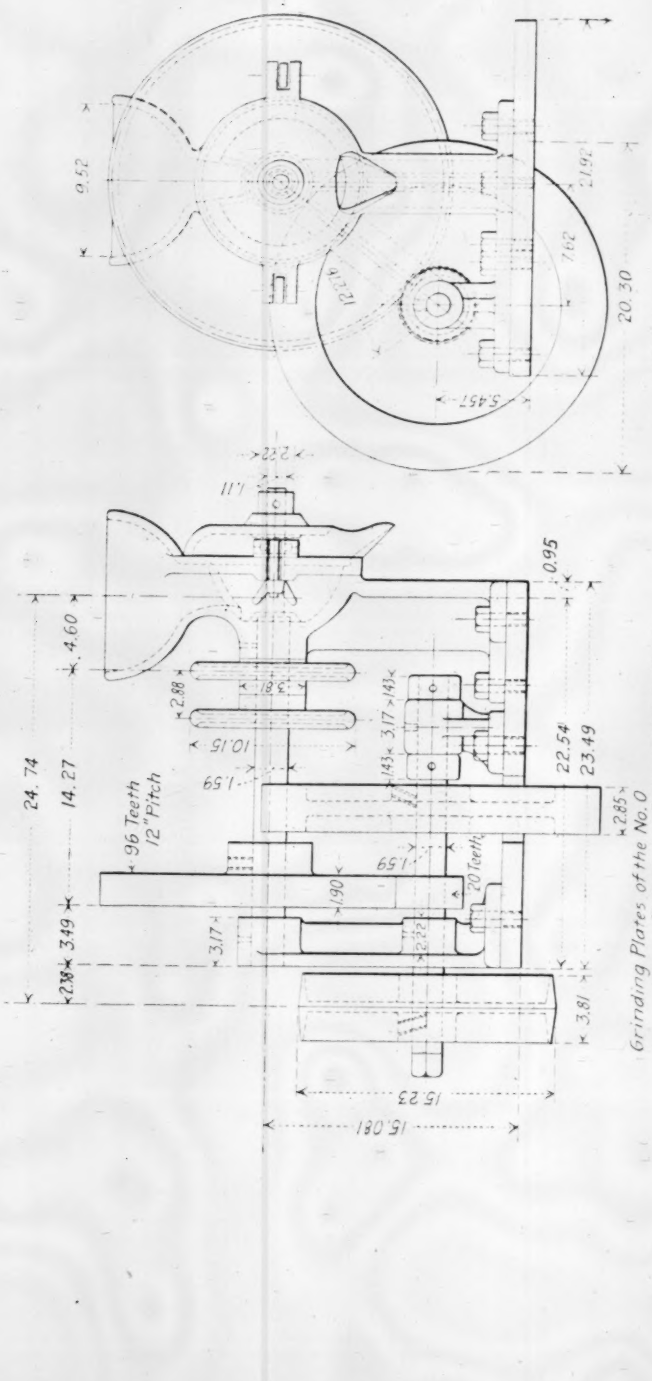
7. Remove the insulation entirely from sufficient wire to give a sample weighing about 25 g. Cut this into small strips and grind slowly, so as not to heat the rubber, in either a No. 0 Enterprise coffee mill, a Russwinn grinder or a mill such as shown by Fig. 2. Adjust the grinder so that not more than 20 per cent will pass through a 40-mesh sieve. Sift all the material through a


Two 2gram Samples of Rubber.
(Make Acetone Extractions)
Acetone Extract. (United)
(Saponify with KOH)
Residue
(Make Chloroform Extraction)
Unsaponifiable Material.
(Dissolve in Alcohol)
Alkali Soluble Acetone Extract.
(Treat with KNO_3 etc.)
Chloroform Extract.
Residue
(Saponify with KOH)
Insoluble Hydrocarbons. A.
Soluble Unsaponifiable Material.
(Treat with CCl_4 & H_2SO_4)
Free Sulfur
Saponifiable Acetone Extract.
Saponifiable Extract.
(Treat with HCl and Ether)
Residue
Hydrocarbons B.
Unsaponifiable Resins.
Residual Solution.
KOH Extract.

Total Waxy Hydrocarbons = A + B.

Weigh Substances with Names Underlined;
Other Substances by Difference.

FIG. 1.—Outline of Method For Rubber Analysis.
(Exclusive of Fillers and Total Sulfur Determinations.)

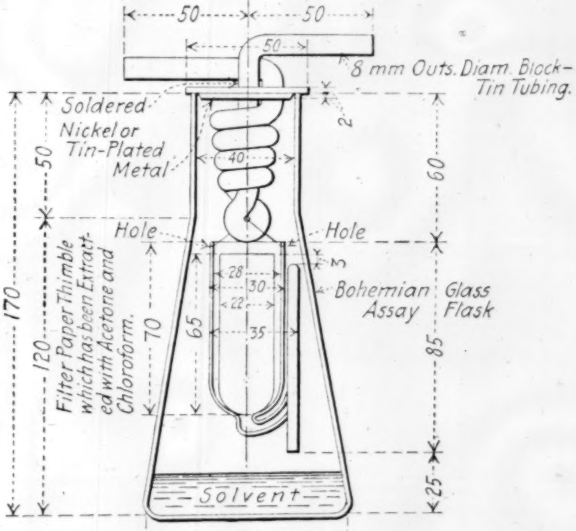

9.52
21.92
7.62
12.776
20.30
5.457
2.22
1.11
0.95
4.60
24.74
14.27
96 Teeth
12" Pitch
2.88
3.81
10.15
1.59
1.43
3.17
1.43
22.54
23.49
2.85
20 Teeth
1.90
1.59
3.49
3.17
2.22
2.38
3.81
15.23
15.081

(All Dimensions in Centimeters)

Grinding Plates of the No. 0 Enterprise Coffee Mill to be Used.

FIG. 2.—Rubber Grinder.

20-mesh sieve, regrinding what is retained on the sieve until the entire sample has passed through. The wires of the sieves shall be evenly spaced in both directions and shall be of 0.016 and 0.010 in. diameter in the 20 and 40-mesh sieves respectively. Remove with a strong magnet any metal that may have come from the grinder and thoroughly mix the sample.


50
50
50
8 mm Outs. Diam. Block-Tin Tubing.
2
Soldered Nickel or Tin-Plated Metal
40
60
50
170
120
Hole
Hole
3
28
30
22
35
Filter Paper Thimble which has been Extracted with Acetone and Chloroform.
70
65
Bohemian Glass Assay Flask
85
25
Solvent
80

(All dimensions in millimeters.)

FIG. 3.—Extraction Apparatus.

EXTRACTION APPARATUS.

8. The extraction apparatus shall conform to Fig. 3. It shall be heated so that the period of filling an empty syphon cup with acetone and completely emptying it, will be between 2½ and 3½ minutes.

PREPARATION OF REAGENTS.

9. Acetone shall be freshly distilled over anhydrous K_2CO_3, using the fraction 56–57° C. **Acetone.**

10. Alcoholic KOH solution shall be of normal strength and shall be made freshly by dissolving the proper amount of KOH (purified by alcohol) in 95 per cent alcohol which has previously been distilled over KOH. The solution shall be allowed to stand for 24 hours and only the clear liquid used. **KOH.**

Ether. 11. Ether shall be washed with three successive portions of distilled water and distilled, using the fraction 34–36° C.

Chloroform. 12. Chloroform shall be pure and freshly distilled.

Carbon Tetrachloride. 13. Carbon tetrachloride shall be pure and freshly distilled.

14. Reagents not otherwise specified shall be c.p. Water shall be distilled.

ACETONE EXTRACT.

Acetone Extract. 15. Extract continuously with 60 cc. of acetone for 8 hours, two 2-g. samples that have been prepared within 24 hours. Unite the extracts in a weighed flask, using hot chloroform to rinse the flasks. Distill off the reagents and dry the flask and contents for 4 hours at 95–100° C. Desiccate until cool and weigh. Continue to dry for 2-hour periods until constant weight is obtained. In drying, place the flask on its side but at a sufficient angle from the horizontal so that the extract does not appreciably run down the side of the flask.

UNSAPONIFIABLE MATERIAL.

Unsaponifiable Matter. 16. Add to the acetone extract 50 cc. of alcoholic KOH solution, boil under a reflux condenser for 2 hours, and evaporate to dryness, removing all alcohol. Add 10 cc. of water and 20 cc. of ether; heat until the wax, etc., are in solution, cool, transfer to a separatory funnel, wash out the flask with warm water and then cool, finally with two 20-cc. portions of ether. The water volume should be 100 cc. and the ether at least 40 cc. Shake vigorously for 2 minutes, and allow the solutions to separate thoroughly. Draw off the aqueous solution into a second funnel, leaving in the first funnel the ethereal solution and any flocculent material that may be present. Again rinse the flask with 20 cc. of ether and add it to the aqueous solution; shake vigorously for 2 minutes, and when separated draw off the aqueous solution and unite in the first funnel the ethereal solutions and any flocculent material. Repeat, shaking with 20-cc. portions of ether until the extraction is complete, using at least 120 cc. of ether. Wash the flask and the funnel, from which the ethereal solution has been taken, with water, until they are free from alkali, subsequently using this wash water to wash the ethereal solution. Continue washing with water until it has been washed twice after it shows no alkaline reaction. Retain with the ethereal solution any flocculent material. Filter the ethereal solution from the flocculent material, through a small pellet of extracted cotton, into a weighed flask, washing first with ether and subsequently with hot chloroform, using this to rinse the original flask and both separatory funnels. Evaporate the solvents and dry the extract to constant weight at 95 to 100° C.; desiccate until cool and weight.

HYDROCARBONS A.

Hydrocarbons A.

17. Add 50 cc. absolute alcohol to the unsaponifiable material and warm until solution is as complete as possible. Cool the solution to −4 or −5° C. and maintain at this temperature for 1 hour by packing the flask in a mixture of ice and salt. Filter out the waxy hydrocarbons, using a funnel packed with ice and salt, and apply suction if necessary. Wash the flask and filter with about 25 cc. of 95 per cent alcohol, which has been previously cooled in the same temperature. Catch the filtrate in a flask which is afterwards cooled to −4 or −5° C. to make sure that all possible waxy hydrocarbons have been removed, and refilter if necessary. Dissolve the residue on the filter paper with hot chloroform, into the original flask. Evaporate the chloroform and dry the flask to constant weight at 95 to 100° C. Cool in a desiccator and weigh.

HYDROCARBONS B.

Hydrocarbons B.

18. Evaporate the alcohol from the flask containing the alcoholic soluble unsaponifiable material, add 25 cc. carbon tetrachloride and transfer to a separatory funnel. Shake with concentrated H_2SO_4, drain off the discolored acid and repeat with fresh portions of acid until there is no longer any discoloration. After drawing off all the acid, wash the carbon tetrachloride solution with repeated portions of water until all traces of acid are removed. Transfer the carbon tetrachloride solution to a weighed flask; evaporate off the solvent and dry the flask to constant weight at 95 to 100° C. Cool in a desiccator and weigh.

FREE SULFUR.

Free Sulfur.

19. Add 2 g. KNO_3 to the aqueous solution and washings from the ethereal separation of the unsaponified material. Evaporate to dryness in a silver or nickel dish and heat to quiet fusion, avoiding contamination with sulfur fumes. Transfer with water to an evaporating dish, acidify with HCl, evaporate to dryness, and dehydrate silica. Add 2 cc. concentrated HCl, take up in water, filter and wash, making a volume of 200 cc.

Heat to boiling and add slowly a slight excess of hot 10-per-cent $BaCl_2$ solution. Allow to stand over night, filter, wash, ignite, weigh the $BaSO_4$ and calculate the sulfur.

DEFINITION OF TERMS DESCRIBING COMPONENTS OF ACETONE EXTRACT.

Organic Extract.

20. The difference between the Acetone Extract and the Free Sulfur shall be called the Organic Extract.

Saponifiable Acetone Extract.

21. The difference between the Organic Extract and the Unsaponifiable Material shall be called the Saponifiable Acetone Extract.

Waxy Hydrocarbon.

22. The sum of the Hydrocarbons A and B shall be called the total Waxy Hydrocarbons.

Unsaponifiable Resins.

23. The difference between the Unsaponifiable Material and the Waxy Hydrocarbons shall be called Unsaponifiable Resins.

CHLOROFORM EXTRACT.

Chloroform Extract.

24. Extract continuously the residues from both of the acetone extractions (without necessarily removing the acetone that may be on them) for 4 hours with 60 cc. of chloroform, unite the extractions in a weighed flask, using hot chloroform to rinse the flasks. Distill off the solvent and dry the flask and contents for 2 hours at 95 to 100° C. Desiccate until cool and weigh. Continue to dry for 1-hour periods until constant weight is obtained. In drying, place the flask on its side but at a sufficient angle from the horizontal so that the extract does not appreciably run down the side of the flask. (If it is needful to wait after the acetone extraction, before starting the chloroform extraction, the sample must be kept in a vacuum of at least 50 mm. of mercury.)

ALCOHOLIC-POTASH EXTRACT.

Alcoholic KOH Extract.

25. Dry the residue from the chloroform extraction at 50 to 60° C. until odor of chloroform can no longer be detected, unite residues from the two 2-g. samples in a 200-cc. Erlenmeyer flask. Add 100 cc. alcoholic KOH solution and boil for 4 hours under a reflux condenser. Filter the solution by decantation through an 11-cc. hardened filter paper into a beaker and wash twice, using each time 25 cc. hot absolute alcohol and then wash thoroughly with hot water. Wash any rubber on the filter paper back into the original flask and reserve this for

the determination of the rubber hydrocarbons. Evaporate the solution to approximate dryness, take up in warm water and transfer to a separatory funnel. Acidify with 15 cc. of 5 normal HCl, using this to rinse the beaker. Add sufficient water to make the bulk of the solution 100 cc. When cool add 40 cc. of ether, using it to rinse the beaker in 20-cc. portions. Shake the aqueous and ethereal solutions thoroughly. After complete separation, draw off the aqueous solution and treat in another separatory funnel, with a fresh 20-cc. portion of ether. Continue to shake the aqueous solution with fresh portions of ether until a colorless portion has been obtained, then shake out twice more. Unite the ethereal solutions and wash with successive additions of water, continuing twice after the water shows no acid reaction. Filter through a plug of extracted cotton into a tared flask, wash the filter and funnel with ether, evaporate the ether without boiling and dry the residue to constant weight at 95 to 100° C. Cool in a desiccator and weigh.

RUBBER HYDROCARBONS.

Rubber Hydrocarbons.

26. Add to the flask containing the rubber residue from the alcoholic KOH extraction, sufficient water to make the total volume of the solution 125 cc. and then add 25 cc. concentrated HCl. Heat for an hour at 97 to 100° C. Decant the supernatant liquid through a hardened filter paper on a Buchner funnel 7 cm. diameter, using suction; wash the residue with 25 cc. hot water and decant. (While a Buchner funnel is recommended, it is permissible to use an 11-cm. hardened filter paper with platinum cone, in a 60-deg. funnel.) Perform this entire treatment with water and HCl three times and save the first and second decantations for the "organic matter" test described in Section 33. The rubber at this stage should be white and practically free from black specks of undissolved fillers; if not, continue the acid treatment until the black specks disappear. (If carbon is present, all the particles of rubber will be grayish, bluish, or black, depending on the form and quantity of carbon used. Black specks in light particles of rubber usually indicate the presence of lead sulfide which must be removed to prevent the formation of lead sulfate on igniting the residue *C*.) Add 150 cc. of hot water to the flask and let stand on a steam bath or hot plate for half an hour and decant through the filter paper, repeating until washings are free from chlorides. (See Section 33.) Transfer all the rubber

in the flask to the filter paper and dry as much as possible by suction. Wash the rubber with 50 cc. of 95-per-cent alcohol, using suction. Transfer the entire residue to a weighing bottle. Dry at 95 to 100° C. for an hour, cool in a vacuum desiccator under reduced pressure and weigh. Dry for a half hour, cool and weigh, repeating this process until either constant weight is reached or the weight starts to increase. Let this weight be represented by *C*. Determine the ash (*E*) on a portion (*D*) of this residue (*C*) and sulfur (*H*) on the remaining portion (*G*). Also determine the sulfur (*F*) on the ash (*E*). Perform the ash determination as described under ash in Rubber Residue and the sulfur determinations as described under Total Sulfur. Then,

$$\text{Rubber hydrocarbons} = 100\,\frac{C}{4}\left(1-\frac{H}{C}-\frac{E-F}{D}\right)$$

expressed as a percentage of the total sample.

ASH IN RUBBER RESIDUE.

Ash in Rubber Residue. 27. Place about 0.5 g. (*D*) of residue *C* into a weighed porcelain crucible and heat gently, gradually driving off the volatile matter. When the crucible has ceased to smoke, raise the temperature gradually to between 450 and 500° C., until all organic matter has been burned away, which is usually indicated by the ash becoming white. (an electric muffle furnace with pyrometer is recommended for this purpose.) Cool in a desiccator and weigh, the weight of ash being represented by *E* in the formula for rubber hydrocarbons. Make sulfur test on ash by the method described under Total Sulfur. If, however, the ash (*E*) is not over 0.08 *D*, the determination of sulfur in the ash may be omitted, and *F* assumed to be zero.

TOTAL SULFUR.

Total Sulfur. 28. Mix a 0.5-g. sample with 4 g. of Na_2O_2 and 6 g. of K_2CO_3 in a dry 15-cc. iron crucible. Cover and heat gradually until the mixture fuses, proceeding cautiously, as rapid heating will cause an explosion, and then bring to quiet fusion for 15 to 20 minutes. Apply the heat so as to avoid contamination with sulfur fumes. Rotate the crucible while the melt solidifies. When cool, put crucible and cover into a casserole containing 200 cc. of water; add 5 to 10 cc. of bromine water and boil until the melt is dissolved. Allow the precipitate to settle, decant the liquid through a thick filter and wash the residue with hot water. Acidify the filtrate with HCl, evaporate to dryness and dehydrate silica; add 2 cc. of concentrated HCl, take up in water, filter and wash, making the total volume about 100 cc. Heat to boiling and add slowly a slight excess of hot 10-per-cent $BaCl_2$ solution. Allow to stand over night, filter, wash, ignite, weigh the $BaSO_4$ and calculate to sulfur.

SPECIFIC GRAVITY.

Specific Gravity.

29. The specific gravity shall be the ratio of the weight of a given volume of the rubber to the weight of an equal volume of water, both at 20° C. Cut strips of the largest applicable size from the conductor and use about 5 g. for the sample. Determine the specific gravity in the usual manner by means of a specific gravity bottle. Care must be taken that no air bubbles adhere to the sample.

CHECKS.

Checks.

30. Specific gravity determinations shall check within 0.01. The other duplicate determinations shall check within the following limits expressed as percentages of the original sample.

DETERMINATION.	CHECK.
Acetone extract	0.10
Saponifiable acetone extract	0.10
Unsaponifiable resins	0.10
Waxy hydrocarbons	0.10
Free sulfur	0.05
Chloroform extract	0.10
Alcoholic potash extract	0.10
Rubber hydrocarbons	0.20
Total sulfur	0.10

INTERPRETATION.

Interpretation.

31. The rubber shall be considered to be the sum of the rubber hydrocarbons, saponifiable acetone extract, unsaponifiable resins and chloroform and alcoholic potash extracts, expressed as percentages. If the chloroform extract is over 3.0 per cent of the rubber so calculated, subtract the excess from the rubber. If the KOH extract is over 1.8 per cent of the rubber as first calculated, subtract this excess also from the rubber.

RED LEAD.

Red Lead.

32. Dissolve 1 g. of the sample in 75 cc. of xylol at a temperature of about 100° C. When the rubber is dissolved, the

absence of any red particles indicates the absence of red lead. If red particles are present, filter the solution into a Gooch crucible and wash thoroughly with benzol, acetone and alcohol successively. Remove the felt and residue to a distilling flask, add HCl, and distill over the chlorine liberated by the lead peroxide, absorbing the gas in a solution of KI and starch. Not more than 0.1 cc. of N/10 thiosulfate shall be required to titrate the iodine liberated.

ORGANIC FILLERS.

Organic Filler.

33. Transfer the first and second decantations of the HCl solutions to a carefully cleaned porcelain dish and add 20 cc. concentrated H_2SO_4. Place dish on steam bath or hot plate to drive off water and HCl. A pronounced charring of the residue indicates the presence of organic matter soluble in water or hydrolyzed by HCl. Examine filter paper and rubber while decanting acid solution and washing free of chlorides. Some types of organic fillers not removed by water and HCl, would be plainly visible at this point. Place a small portion of residue *C* under a microscope and examine for fibrous and other characteristic organic material. If organic fillers are indicated and not clearly proven by this test, place 1 g. of the original sample in a beaker, add 50 cc. of xylol and heat on hot plate until the rubber is dissolved. Decant xylol solution and wash residue with ether several times by decantation. Dry residue and examine under the microscope.

STATEMENT OF RESULTS.

Statement of Results.

34. The results of the analysis shall be stated in the following form:

	PER CENT.
Acetone extract	....
Saponifiable acetone extract	....
Unsaponifiable resins	....
Waxy hydrocarbons	....
Free sulfur	....
Chloroform extract	....
Alcoholic potash extract	....
Total sulfur	....
Rubber	....
Color of acetone extract (60 cc. vol.)	....
Fluorescence in acetone extract solution (present or absent)	....
Hydrocarbons A (consistency and color)	....
Hydrocarbons B (solid or liquid)	....
Color of chloroform extract (60 cc. vol.)	....
Carbon (present or absent)	....
Red lead (present or absent)	....
Specific gravity	....

TENTATIVE SPECIFICATIONS
FOR
COTTON RUBBER-LINED FIRE HOSE FOR PRIVATE FIRE DEPARTMENT USE.[1]

Serial Designation: D 14 – 21 T.

These specifications are issued under the fixed designation D 14; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications apply to $2\frac{1}{2}$-in. single-jacketed cotton, rubber-lined fire hose for use in private fire departments.

I. MANUFACTURE.

Cotton Fabric. 2. (*a*) The jacket shall be well, evenly and firmly made from good cotton, as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with good manufacturing practice.

(*b*) The cotton jacket shall be seamless and have the fillers woven around the hose throughout its length and the warps interwoven with and covering the fillers.

Rubber Lining. 3. (*a*) The lining shall be made of a properly vulcanized rubber compound which will comply with all of the tests specified in Section 7. It shall consist of not less than three calendered sheets in one solid body and shall be lap-jointed with the lap as small and neat as is consistent with good results.

(*b*) The lining shall be smooth and practically free from pitting and other imperfections and from corrugations.

(*c*) The lining shall be of uniform thickness and not less than 0.058 nor more than 0.072 in. in thickness exclusive of the backing.

(*d*) The backing, if used, shall not exceed 0.028 in. in thickness. It need not be of the same composition as the rubber lining, but the adhesion between the rubber lining and the cotton jacket shall comply with the test specified in Section 8.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Cotton Rubber-Lined Fire Hose for Private Department Use. The Standard Specifications, which were last published under the Serial Designation D 14 – 15, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products Room 850, 466 Lexington Ave., New York City.

Flexibility. 4. The hose shall be flexible and easily coiled.

Workmanship. 5. The character of the workmanship shall be such as is incident to good manufacturing practice.

II. PHYSICAL PROPERTIES AND TESTS.

Standard Methods. 6. The tests necessary to determine the physical properties which are prescribed in the following sections shall be made in accordance with the appropriate section of those numbered from 17 to 26 inclusive of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1]

Tests of Rubber Lining. 7. (*a*) The tensile strength shall be not less than 1600 lb. per sq. in. when tested one month or less from date of final vulcanization, and not less than 1200 lb. per sq. in. when tested more than one month but not over one year from date of final vulcanization.

(*b*) The tensile strength after subjection to a dry heat of 158° F. (70° C.) for a period of four successive days of 24 hours each shall be not less than 900 lb. per sq. in. This test shall be made within three months from date of final vulcanization.

(*c*) The elongation when rupture occurs in making the tensile test (Paragraph (*a*)) shall be such that the original 2-in. gage length shall stretch to not less than 12 in., when tested one month or less from date of final vulcanization, and not less than 10 in. when tested more than one month but not over one year from date of final vulcanization.

(*d*) The permanent elongation or set following a stretch from 2 to 10 in. shall not exceed 25 per cent when tested one month or less from date of vulcanization. When tested more than one month but not over one year from date of final vulcanization, the stretch shall be 2 to 8 in. instead of 2 to 10 in.

Friction Test. 8. The adhesion between the lining and the cotton jacket shall be such that the rate of separation of the lining from the jacket of a test piece $1\frac{1}{2}$ in. in width shall be not greater than one inch per minute with the application of a weight of 12 lb.

Hydrostatic Pressure Tests. 9. (*a*) Each length of hose shall be subjected to a hydrostatic pressure of 300 lb. per sq. in. for five seconds without leaking in the hose or at the couplings or breaking any threads in the jacket.

(*b*) A 3-ft. sample in every lot of 3000 ft. of hose or less shall, while lying either straight or curved to a radius of 27 in., withstand without failure a hydrostatic pressure of 500 lb. per sq. in.

(*c*) One full length in every lot of 500 ft. of hose or less shall, while kinked, withstand without failure a hydrostatic pressure of 250 lb. per sq. in. applied for five seconds.

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[1] 1921 Book of A.S.T.M. Standards.

10. The elongation of the hose when tested as prescribed in Section 9 (*a*) shall not exceed 13 per cent of the length measured under a pressure of 10 lb. per sq. in. **Elongation.**

11. The hose shall not twist more than 25 deg. per ft. when tested as prescribed in Section 9 (*a*). The twisting shall be in the direction which will tighten rather than loosen the couplings. **Twisting.**

12. When subjected to the test prescribed in Section 9 (*a*), the hose shall not rise more than 4 in. from the level of the test table or test floor or warp more than 20 in. from a straight line drawn from center to center of the couplings. **Warping.**

III. CHEMICAL PROPERTIES AND TESTS.

13. The chemical tests required by the following chemical requirements shall be made in accordance with the appropriate section of those numbered from 1 to 16 inclusive of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1] **Methods.**

14. (*a*) In the analysis of the rubber lining, the acetone extract shall not exceed 4 per cent; the alcoholic potash extract shall not exceed $1\frac{1}{2}$ per cent; the chloroform extract shall not exceed 2 per cent; the ash shall be not less than 50 per cent nor more than 57 per cent; the total sulfur (excluding barytes) shall not exceed 4 per cent; and the free sulfur shall not exceed $1\frac{1}{4}$ per cent. All percentages shall be by weight of the total compound. **Analysis of Rubber Lining.**

(*b*) The sum total of the results of the tests of the rubber lining for acetone extract, alcoholic potash extract, chloroform extract, ash and total sulfur (exclusive of barytes) shall not exceed 67 per cent by weight of the total compound.

IV. DIMENSIONS AND WEIGHTS.

15. The hose shall have an internal diameter of not less than $2\frac{1}{2}$ in. and shall be furnished in lengths averaging 50 ft. **Diameter and Length of Hose.**

16. Each 50-ft. length of hose complete with couplings shall weigh not less than 40 lb. **Weight of Hose.**

V. COUPLINGS.

17. Couplings shall be of the type ordered but unless otherwise specified, they shall conform to Sections 18 to 23 inclusive, and Section 26. **Type.**

18. The couplings shall be made, finished and fitted in a workmanlike manner throughout. The diameter through couplings shall be $2\frac{1}{2}$ in. **Workmanship and Diameter.**

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[1] 1921 Book of A.S.T.M. Standards.

Type and Dimensions. 19. The couplings shall be of the expansion-ring pattern, of ample strength, and of the best form to resist the stress of expanding the binding ring in the coupling, and shall have a tail part sufficiently long to extend $\frac{1}{8}$ in. beyond the end of the expansion ring. The ring shall be at least $1\frac{1}{4}$ in. in length.

Chemical Composition. 20. The couplings shall be made of an alloy of copper, tin and zinc (and lead if desired) of the following proportions:

Copper	not under	83	per	cent
Tin	" "	5	"	"
Zinc	" over	7	"	"
Lead	" "	3	"	"

Weight. 21. The weight of couplings, including both male and female and expansion rings, shall be not less than 5 lb.

Gasket and Washer. 22. (*a*) The couplings shall be provided with rubber gaskets of the same quality as the rubber lining, at least $\frac{1}{8}$ in. thick, and accurately fitted.

(*b*) The couplings shall have, inside each expansion ring, a rubber washer at least $\frac{3}{16}$ in. in thickness and with inside diameter not less than that of the coupling.

Thread. 23. The threads of hose couplings shall be interchangeable with those in use in the city or town where the hose will be used. Wherever practicable and not otherwise specified, the thread shall be the "National Standard" thread adopted in 1906 by the National Fire Protection Association.

Attachment of Couplings. 24. The couplings shall be attached to the hose in a workmanlike manner without cutting the lining or rupturing the cotton jacket. They shall withstand the hydrostatic pressure tests described in Section 9 (*a*) without the use of tape or rubber tissue as a filler.

NOTE.

It is recommended that the couplings be ordered to conform to the "Standard for Fire Hose Couplings" (see Sections 18 to 23 inclusive) and provided with the "National Standard" thread of the National Fire Protection Association. The essential features of this thread are a 60-deg. V-thread, outside diameter on the male thread of $3\frac{1}{16}$ in. and $7\frac{1}{2}$ threads per inch.

In private yards located in cities or towns where couplings having 7, $7\frac{1}{2}$ or 8 threads per inch, and outside diameters on the male ends of not less than $3\frac{1}{32}$ in. or more than $3\frac{5}{64}$ in. are in use, it is possible to render both male and female couplings adaptable for interchange with the Standard by the use of an adjustable tap for the female end or an adjustable die for the male end of the coupling. This tap or die should have the same number of threads per inch as the coupling or nipple to be treated. In cases where the thread in use does not come within the above limits, both with respect to number of threads per inch and outside diameter of threads on male, the hydrant nipples can be equipped with adapters provided with spanner lugs and having a Standard male thread on the out-board end.

VI. MARKING.

Hose. 25. Beginning at a point approximately 4 ft. from the couplings, each 50-ft. length of hose shall be stenciled at two places in black indelible letters 1 in. high with the legend "A.S.T.M. Specifications", the name of the manufacturer, the month and year of manufacture and the words "Tested at 300 lb."

Couplings. 26. Both male and female couplings shall be stamped with the name of the manufacturer and the month and year of manufacture in letters and figures not less than $\frac{1}{8}$ in. high.

VII. INSPECTION AND REJECTION.

Inspection. 27. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the hose to permit of arrangement for inspection.

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the hose is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hose in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection. 28. (*a*) Each length of hose that fails in the tests prescribed in Sections 9 (*a*), 10, 11 or 12 shall be rejected.

(*b*) In the case of failure to pass the tests prescribed in Sections 7, 8, 9 (*b*) or 9 (*c*), two additional samples shall be subjected to the test in which failure occurred. If either of these two additional samples fails, the lot of hose from which it was taken shall be rejected.

Rehearing. 29. Samples of rejected hose shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
COTTON RUBBER-LINED FIRE HOSE FOR PUBLIC FIRE DEPARTMENT USE.[1]

Serial Designation: D 26 – 21 T.

These specifications are issued under the fixed designation D 26; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications apply to $2\frac{1}{2}$, 3 and $3\frac{1}{2}$-in., double-jacketed cotton, rubber-lined fire hose for use in public fire departments.

I. MANUFACTURE.

Cotton Fabric. 2. (*a*) The two jackets shall be well, evenly and firmly made from good cotton, as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with good manufacturing practice.

(*b*) Each jacket shall be seamless and have the fillers woven around the hose throughout its length and the warps interwoven with and covering the fillers. The two jackets may be separate or interwoven.

Rubber Lining. 3. (*a*) The lining shall be made of a properly vulcanized rubber compound which will comply with all the tests specified in Section 7. It shall consist of not less than three calendered sheets in one solid body and shall be lap-jointed with the lap as small and as neat as is consistent with good results.

(*b*) The lining shall be smooth and practically free from pitting and other imperfections and from corrugations.

(*c*) The lining shall be of uniform thickness and within the following limits of thickness exclusive of backing:

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Cotton Rubber-lined Fire Hose for Public Fire Department Use. The Standard Specifications, which were last published under the serial designation D 26 – 18, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

INTERNAL DIAMETER OF HOSE, IN.	MINIMUM THICKNESS, IN.	MAXIMUM THICKNESS, IN.
2½	0.058	0.072
3	0.058	0.072
3½	0.072	0.095

(*d*) The backing, if used, shall not exceed 0.028 in. in thickness. It need not be of the same composition as the rubber lining but the adhesion between the rubber lining and the cotton jacket shall comply with the test specified in Section 8.

Flexibility. 4. The hose shall be flexible and easily coiled.

Workmanship. 5. The character of the workmanship shall be such as is incident to good manufacturing practice.

II. PHYSICAL PROPERTIES AND TESTS.

Standard Methods. 6. The tests necessary to determine the physical properties which are prescribed in the following sections shall be made in accordance with the appropriate section of those numbered from 17 to 26 inclusive, of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1]

Tests of Rubber Lining. 7. (*a*) The tensile strength shall be not less than 1600 lb. per sq. in. when tested one month or less from date of final vulcanization and not less than 1200 lb. per sq. in. when tested more than one month but not over one year from date of final vulcanization.

(*b*) The tensile strength after subjection to a dry heat of 158° F. (70° C.) for a period of four successive days of 24 hours each shall be not less than 900 lb. per sq. in. This test shall be made within three months from date of final vulcanization.

(*c*) The elongation when rupture occurs in making the tensile test (Paragraph (*a*)) shall be such that the original 2-in. gage length shall stretch to not less than 12 in. when tested one month or less from date of final vulcanization and not less than 10 in. when tested more than one month but not over one year from date of final vulcanization.

(*d*) The permanent elongation or set following a stretch from 2 to 10 in. shall not exceed 25 per cent when tested one month or less from date of vulcanization. When tested more than one month but not over one year from date of final vulcanization, the stretch shall be 2 to 8 in. instead of 2 to 10 in.

Friction Test 8. The adhesion between the lining and the cotton jackets shall be such that the rate of separation of the lining from the jackets of a test piece $1\frac{1}{2}$ in. in width shall be not greater than 1 in. per minute with the application of a weight of 12 lb.

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[1] 1921 Book of A.S.T.M. Standards.

Hydrostatic Pressure Tests.

9. (*a*) Each length of hose shall be subjected to a hydrostatic pressure of 400 lb. per sq. in. for five seconds without leaking in the hose or at the couplings or breaking any threads in the jackets.

(*b*) A 3-ft. sample in every lot of 3000 ft. of hose or less shall, while lying either straight or curved to a radius of 27 in., withstand without failure a hydrostatic pressure of 600 lb. per sq. in.

(*c*) One full length in every lot of 500 ft. of hose or less shall, while kinked, withstand without failure a hydrostatic pressure of 300 lb. per sq. in. for $2\frac{1}{2}$-in. hose and 250 lb. per sq. in. for 3 and $3\frac{1}{2}$-in. hose applied for 5 seconds.

Elongation.

10. The elongation of the hose when tested as prescribed in Section 9 (*a*) shall not exceed 9 per cent of the length, measured under a pressure of 10 lb. per sq. in.

Twisting.

11. The hose shall not twist more than 15 deg. per ft. when tested as prescribed in Section 9 (*a*). The twisting shall be in the direction which will tighten rather than loosen the couplings.

Warping.

12. When subjected to the test prescribed in Section 9 (*a*), the hose shall not rise from the level of the test table or test floor, or warp more than 20 in. from a straight line drawn from center to center of the couplings.

III. CHEMICAL PROPERTIES AND TESTS.

Methods.

13. The chemical tests required by the following chemical requirements shall be made in accordance with the appropriate section of those numbered from 1 to 16 inclusive, of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1]

Analysis of Rubber Lining.

14. (*a*) In the analysis of the rubber lining, the acetone extract shall not exceed 4 per cent; the alcoholic potash extract shall not exceed $1\frac{1}{2}$ per cent; the chloroform extract shall not exceed 2 per cent; the ash shall be not less than 50 per cent nor more than 57 per cent; the total sulfur (excluding barytes) shall not exceed 4 per cent; and the free sulfur shall not exceed $1\frac{1}{4}$ per cent. All percentages shall be by weight of the total compound.

(*b*) The sum total of the results of the tests of the rubber lining for acetone extract, alcoholic potash extract, chloroform extract, ash and total sulfur (exclusive of barytes) shall not exceed 67 per cent by weight of the total compound.

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[1] 1921 Book of A.S.T.M. Standards.

IV. DIMENSIONS AND WEIGHTS.

Diameter and Length of Hose. 15. The hose shall have an internal diameter of not less than $2\frac{1}{2}$, 3 or $3\frac{1}{2}$ in. as ordered and shall be furnished in lengths averaging 50 ft.

Weight. 16. The weight of each 50-ft. length of hose complete with couplings shall not exceed the following limits:

INTERNAL DIAMETER OF HOSE, IN.	MAXIMUM WEIGHT PER 50-FT. LENGTH, LB.
$2\frac{1}{2}$	70
3	93
$3\frac{1}{2}$	115

V. COUPLINGS.

Type. 17. Couplings shall be as ordered but unless otherwise specified they shall conform to Sections 18 to 23 inclusive, and Section 26.

Workmanship and Diameter. 18. The couplings shall be made, finished and fitted in a workmanlike manner throughout. The diameter through couplings shall be according to the size of the hose: namely $2\frac{1}{2}$, 3 or $3\frac{1}{2}$ in.

Type and Dimensions. 19. The couplings shall be of the expansion-ring pattern, of ample strength, and of the best form to resist the stress of expanding the binding ring in the coupling. and shall have a tail part sufficiently long to extend $\frac{1}{8}$ in. beyond the end of the expansion ring. They shall be fitted with expansion rings of the following lengths:

INTERNAL DIAMETER OF HOSE, IN.	LENGTH OF EXPANSION RINGS, IN.
$2\frac{1}{2}$	$1\frac{1}{2}$
3	$1\frac{3}{4}$
$3\frac{1}{2}$	$2\frac{1}{2}$

Chemical Composition. 20. The couplings shall be made of an alloy of copper, tin and zinc (and lead if desired) of the following proportions:

Copper	not under	83	per cent
Tin	“ “	5	“ “
Zinc	“ over	7	“ “
Lead	“ “	3	“ “

Weight. 21. The weight of couplings, including both male and female and expansion rings, shall conform to the following minimum requirements:

INTERNAL DIAMETER OF HOSE, IN.	MINIMUM WEIGHT PER SET OF COUPLINGS, LB.
$2\frac{1}{2}$	$5\frac{3}{4}$
3	8
$3\frac{1}{2}$	$12\frac{1}{2}$

Gasket and Washer. 22. (*a*) The couplings shall be provided with rubber gaskets of the same quality as the rubber lining, and accurately fitted.

(*b*) The couplings shall have, inside each expansion ring, a rubber washer with inside diameter not less than that of the coupling and thickness not less than the following:

INTERNAL DIAMETER OF HOSE, IN.	THICKNESS OF WASHER, IN.
$2\frac{1}{2}$	$\frac{3}{16}$
3	$\frac{1}{4}$
$3\frac{1}{2}$	$\frac{1}{4}$

Thread. 23. The threads of hose couplings shall be interchangeable with those in use in the city or town where the hose will be used. Wherever practicable the thread shall be the "National Standard" thread adopted in 1906 by the National Fire Protection Association.

Attachment of Couplings. 24. The couplings shall be attached to the hose in a workmanlike manner without cutting the lining or rupturing the cotton jacket. They shall withstand the hydrostatic pressure tests described in Section 9 (*a*) without the use of tape or rubber tissue as a filler.

NOTE.

It is recommended that couplings be ordered to conform to the "Standard for Fire Hose Couplings" (see Sections 18 to 23 inclusive) and provided with the "National Standard" thread of the National Fire Protection Association. The essential features of this thread are a 60-deg. V-thread and the following:

SIZE OF COUPLINGS, IN.	NUMBER OF THREADS PER IN.	OUTSIDE DIAMETER OF MALE THREADS, IN.
$2\frac{1}{2}$	$7\frac{1}{2}$	$3\frac{1}{16}$
3	6	$3\frac{5}{8}$
$3\frac{1}{2}$	6	$4\frac{1}{4}$

In many cases where the number of threads and the outside diameters of the male ends do not differ greatly from the Standard, it is possible to render both male and female couplings adaptable for interchange with the Standard by the use of an adjustable tap for the female end or an adjustable die for the male end of the coupling. This tap or die should have the same number of threads per inch as the coupling or nipple to be treated.

In cases where the above change in the existing equipment cannot be made, the hydrant nipples can be equipped with adapters provided with spanner lugs and having a Standard male thread on the out-board end.

VI. MARKING.

Hose. 25. Beginning at a point approximately 4 ft. from the couplings, each 50-ft. length of hose shall be stenciled at two places in black indelible letters 1 in. high with the legend "A.S.T.M. Specifications", the name of the manufacturer, the month and year of manufacture and the words "Tested at 400 lb."

26. Both male and female couplings shall be stamped with the name of the manufacturer and the month and year of manufacture in letters and figures not less than $\frac{1}{8}$ in. high. **Couplings.**

VII. INSPECTION AND REJECTION.

27. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the hose to permit of arrangement for inspection. **Inspection.**

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the hose is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hose in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

28. (*a*) Each length of hose that fails in the tests prescribed in Sections 9 (*a*), 10, 11 or 12 shall be rejected. **Rejection.**

(*b*) In the case of failure to pass the tests prescribed in Sections 7, 8, 9 (*b*) or 9 (*c*), two additional samples shall be subjected to the test in which failure occurred. If either of these two additional samples fails, the lot of hose from which it was taken shall be rejected.

29. Samples of rejected hose shall be preserved for two weeks from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time. **Rehearing.**

TENTATIVE SPECIFICATIONS

FOR

WRAPPED AIR HOSE FOR USE WITH PNEUMATIC TOOLS.[1]

Serial Designation: D 46 – 21 T.

These specifications are issued under the fixed designation D 46; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover wrapped air hose for use with pneumatic drills, hammers, hoists and other devices working at not more than 125-lb. pressure and for vacuum cleaning outfits.

I. MANUFACTURE.

Construction. 2. The hose shall consist of:

(*a*) An inner rubber tube;
(*b*) Reinforcement of plies of cotton duck;
(*c*) An outer rubber cover;
(*d*) A protective covering of wire armor or a woven cotton jacket when specified.

Rubber Tube. 3. The rubber tube shall be smooth, uniform in quality and thickness, and free from injurious defects.

Cotton Reinforcement. 4. (*a*) The reinforcement shall consist of plies of cotton duck cut on a bias of approximately 45 deg., and applied evenly and firmly over the tube with not less than a $\frac{1}{2}$-in. lap. The number of plies shall be as specified in Table I. The plies of duck shall be well frictioned on both sides with a rubber compound which shall firmly join the plies to the rubber tube and cover and to each other.

(*b*) The cotton shall be as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with the best manufacturing practice.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Air-Line Hose for Pneumatic Tools. The Standard Specifications, which were last published under the Serial Designation: D 46–18, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

(*c*) The reinforcement shall be sufficiently strong to enable the hose to successfully withstand the hydrostatic pressure test and yet at the same time be soft and pliable.

TABLE I.—NUMBER OF PLIES.

INSIDE DIAMETER OF HOSE, IN.	NUMBER OF PLIES.
$\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$	4
1, $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{1}{2}$	5

Rubber Cover.

5. The rubber cover shall be uniform in quality and thickness, and free from injurious defects.

Extra Coverings.

6. The extra coverings of wire armor or woven cotton jacket when specified shall be as follows:

(*a*) The wire, armor shall be $\frac{3}{16}$-in. half-round galvanized steel wire, wrapped with $\frac{1}{4}$-in. space between adjacent turns.

(*b*) The weight of the woven cotton jacket per linear foot shall be not less than the following:

SIZE OF HOSE, IN.	MINIMUM WEIGHT, OZ. PER LIN. FT.
$\frac{3}{8}$	$\frac{3}{4}$
$\frac{7}{16}$	$\frac{7}{8}$
$\frac{1}{2}$	1
$\frac{5}{8}$	$1\frac{1}{4}$
$\frac{3}{4}$	$1\frac{1}{2}$
1	2
$1\frac{1}{8}$	$2\frac{1}{4}$
$1\frac{1}{4}$	$2\frac{1}{2}$
$1\frac{1}{2}$	3

II. PHYSICAL PROPERTIES AND TESTS.

Standard Methods.

7. The tests necessary to determine the physical properties which are prescribed in the following sections shall be made in accordance with the appropriate section of those numbered from 18 to 20 and 22 to 26, inclusive, of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1]

Test Sample.

8. A sample 52 in. long shall be cut from each lot of 500 ft. of hose or less and subjected to the following tests.

Tests of Tube and Cover.

9. (*a*) Test specimens shall be cut longitudinally from the sample of hose.

(*b*) The tensile strength shall be not less than 1500 lb. per sq. in. for the tube and 1300 lb. per sq. in. for the cover.

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[1] 1921 Book of A.S.T.M. Standards.

(*c*) The elongation at the breaking load for both the tube and the cover shall be such that the original 2-in. gage length of the test specimens shall stretch to not less than $10\frac{1}{2}$ in.

(*d*) The set, or permanent elongation, following a stretch from 2 in. to 9 in. shall not exceed 25 per cent.

Friction Test. 10. The adhesion between the plies shall be determined by suspending a 15-lb. weight from the separated end of a ply of a 1-in. test ring cut from the 52-in. sample described in Section 8, the force being applied radially. The rate of separation of the plies shall be not greater than 1 in. per minute. The test shall extend for ten minutes when the size of the test ring permits.

Hydrostatic Pressure Tests. 11. From the 52-in. sample, a piece of hose 3 ft. long shall be taken and subjected to a hydrostatic test at the pressure specified in Table II for hose of its size.

The test shall continue for five minutes and the hose shall withstand the pressure without bursting or developing leaks or other defects. The wire protective covering shall be removed from protected hose prior to this test.

On large orders the number of tests may be reduced to not less than three at the option of the inspector representing the purchaser.

TABLE II.—TEST PRESSURES.

INSIDE DIAMETER OF HOSE, IN.	TEST PRESSURE, LB. PER SQ. IN.
$\frac{3}{8}$	750
$\frac{7}{16}$	725
$\frac{1}{2}$	700
$\frac{5}{8}$	650
$\frac{3}{4}$	650
1	600
$1\frac{1}{8}$	600
$1\frac{1}{4}$	550
$1\frac{1}{2}$	550

III. STANDARD SIZES AND DIMENSIONS.

Length. 12. Unless otherwise specified, the hose shall be furnished in 50-ft. lengths. The ends of each length shall be uncapped and without fittings.

Size and Thickness. 13. The minimum thicknesses shall be $\frac{3}{32}$ in. for the rubber tube and $\frac{1}{16}$ in. for the rubber cover.

IV. MARKING.

Marking. 14. Each 50-ft. length of hose shall have inlaid in the rubber cover in three places, namely, midway between the ends and within 10 ft. of each end, a brand showing the name of the manufacturer, the month and year of manufacture, the trade name of the hose, and the legend "Wrapped-Air 125 lb. A.S.T.M. Specifications."

V. INSPECTION AND REJECTION.

Inspection.

15. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the hose to permit of arrangement for inspection.

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the hose is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hose in his own laboratory or elsewhere. But such tests shall be made within 60 days after date of shipment and at the expense of the purchaser.

Rejection.

16. (*a*) If the sample fails to meet the requirements of Section 9 the lot from which it was taken shall be rejected.

(*b*) If the sample fails to meet the requirements of either Section 10 or 11 two additional samples shall be tested. If either sample fails the lot from which it was taken shall be rejected.

Rehearing.

17. Samples of rejected hose shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the test, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS

FOR

BRAIDED AIR HOSE FOR USE WITH PNEUMATIC TOOLS.[1]

Serial Designation: D 60 - 21 T.

These specifications are issued under the fixed designation D 60; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered

1. These specifications cover braided air hose for use with pneumatic hammers, drills, hoists and other devices working at not more than 125-lb. pressure, and for vacuum cleaning outfits.

I. MANUFACTURE.

Construction

2. The hose shall consist of:

(*a*) An inner rubber tube;
(*b*) Reinforcement of plies of braided cotton;
(*c*) An outer rubber cover;
(*d*) A protective covering of wire armor or a woven cotton jacket when specified.

Rubber Tube.

3. The rubber tube shall be smooth, uniform in quality and thickness, and free from injurious defects.

Cotton Reinforcement.

4. (*a*) The reinforcement shall consist of three plies of braided cotton evenly and firmly woven over the rubber tube. The plies of braid shall be well impregnated with a rubber compound which shall firmly join the plies to the rubber tube and rubber cover and to each other. There shall be a sufficient coating of rubber compound between the plies so as to form a distinct layer of rubber.

(*b*) The cotton shall be as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with the best manufacturing practice.

(*c*) The reinforcement shall be sufficiently strong to enable the hose to successfully withstand the hydrostatic pressure test, yet at the same time be soft and pliable.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Leader Hose for Use with Pneumatic Tools. The standard specifications, which were last published under the Serial Designaton: D 60-20, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

Rubber Cover. 5. The rubber cover shall be uniform in quality and thickness, and free from injurious defects.

Extra Coverings. 6. When extra coverings of wire armor or braided cotton are specified, they shall be applied as follows:

(*a*) The wire armor shall be $\frac{3}{16}$-in. half-round galvanized steel wire, wrapped with $\frac{1}{4}$ in. space between adjacent turns.

(*b*) The weight of the woven cotton jacket per linear foot shall be not less than the following values:

SIZE OF HOSE, IN.	MINIMUM WEIGHT OZ. PER LIN. FT.
$\frac{3}{8}$	$\frac{3}{4}$
$\frac{7}{16}$	$\frac{7}{8}$
$\frac{1}{2}$	1
$\frac{5}{8}$	$1\frac{1}{4}$
$\frac{3}{4}$	$1\frac{1}{2}$
1	2
$1\frac{1}{8}$	$2\frac{1}{4}$
$1\frac{1}{4}$	$2\frac{1}{2}$
$1\frac{1}{2}$	3

II. PHYSICAL PROPERTIES AND TESTS.

Standard Methods. 7. The tests necessary to determine the physical properties which are prescribed in the following sections shall be made in accordance with the appropriate section of those numbered from 18 to 20 and 22 to 26, inclusive, of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1]

Test Sample. 8. A sample 52 in. long shall be cut from each lot of 500 ft. of hose or less and subjected to the following tests.

Tests of Tube and Cover. 9. (*a*) Test specimens shall be cut longitudinally from the sample of hose.

(*b*) The tensile strength shall be not less than 800 lb. per sq. in. for the tube and 700 lb. per sq. in for the cover.

(*c*) The elongation at the breaking load for both the tube and the cover shall be such that the original 2-in. gage length of the test specimens shall stretch to not less than 8 in. for the tube and 7 in. for the cover.

(*d*) The set, or permanent elongation following a stretch from 2 in. to 6 in. shall not exceed 25 per cent in either tube or cover.

Friction Test. 10. The adhesive quality of the rubber binding the plies together shall be determined by suspending a 15-lb. weight from the separated end of a ply of a specimen 1 in. wide, cut transversely from the 52-in.

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[1] 1921 Book of A.S.T.M. Standards.

sample described in Section 8. The rate of separation of the plies shall be not greater than 1 in. per minute.

Hydrostatic Test. 11. From the 52-in. sample described in Section 8, a piece of hose 3 ft. long shall be taken and subjected to a hydrostatic test at the pressure specified in Table I for hose of its size.

The test shall continue for five minutes and the hose shall withstand the pressure without bursting or developing leaks or other defects. The protective covering shall be removed from protected hose prior to this test.

On large orders the number of tests may be reduced to not less than three at the option of the inspector representing the purchaser.

TABLE I.—TEST PRESSURES.

INSIDE DIAMETER OF HOSE, IN.	TEST PRESSURE, LB. PER SQ IN.
$\frac{3}{8}$	950
$\frac{7}{16}$	925
$\frac{1}{2}$	900
$\frac{5}{8}$	850
$\frac{3}{4}$	750
1	700
$1\frac{1}{8}$	650
$1\frac{1}{4}$	600
$1\frac{1}{2}$	550

III. STANDARD DIMENSIONS AND WEIGHTS.

Length. 12. Unless otherwise specified, the hose shall be furnished in 50-ft. lengths. The ends of each length shall be uncapped and without fittings.

Thickness. 13. (*a*) The minimum wall thicknesses shall be $\frac{3}{32}$ in. for the rubber tube and $\frac{1}{16}$ in. for the rubber cover.

(*b*) The gage of the tube and cover shall be measured with the braid embedded in the rubber.

IV. MARKING.

Marking. 14. Each 50-ft. length of hose shall have inlaid in the rubber cover in three places, namely, midway between the ends and within 10 ft. of each end, a brand showing the name of the manufacturer, the month and year of manufacture, the trade name of the hose and the legend "Braided-Air 125 lb. A.S.T.M. Specifications."

V. INSPECTION AND REJECTION.

Inspection. 15. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the hose to permit of arrangement for inspection.

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the hose is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hose in his own laboratory or elsewhere. Such tests shall be made within 60 days after date of shipment and at the expense of the purchaser.

Rejection.

16. (*a*) If the sample fails to meet the requirements of Section 9, the lot from which it was taken shall be rejected.

(*b*) If the sample fails to meet the requirements of either Section 10 or 11, two additional samples shall be tested. If either sample fails, the lot from which it was taken shall be rejected.

Rehearing.

17. Samples of rejected hose shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
STEAM HOSE.[1]

Serial Designation: D 54 – 21 T.

These specifications are issued under the fixed designation D 54; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover wrapped steam hose suitable for steam heat connections when the steam pressure does not exceed 125 lb. per sq. in.

I. MANUFACTURE.

Construction. 2. The hose shall consist of:

(*a*) An inner rubber tube;
(*b*) Cotton duck reinforcement;
(*c*) An outer rubber cover.

Rubber Tube. 3. The inner rubber tube shall be smooth, uniform in quality and thickness, and free from injurious defects.

Cotton Reinforcement. 4. The reinforcement shall consist of long-fiber cotton duck of 5 ply yarn. and not less than 16 nor more than 22 picks per inch of width, for both warp and filler. The duck shall be cut and applied on a bias of from 42 to 46 deg. with edges lapped at least 0.5 in. and with both sides well frictioned with a rubber compound suitable for the required service.

Rubber Cover. 5. The outer rubber cover shall be uniform in quality and thickness, and free from injurious defects.

II. PHYSICAL PROPERTIES AND TESTS.

Standard Methods. 6. The tests necessary to determine the physical properties which are prescribed in the following sections shall be made in accordance with the appropriate section of those numbered from 18 to 25 of the Standard Methods of Testing Cotton Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[2]

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Steam Hose. The Standard Specifications, which were last published under the serial designation D 54 – 20, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

[2] 1921 Book of A.S.T.M. Standards.

Test Samples.

7. A portion 18 in. long shall be cut from each length of hose, except in the case of 22, 24 or 30-in. lengths, when one length from each 200 ft. or less shall be taken for test. A portion $2\frac{1}{2}$ in. long shall be cut from the test specimen and subjected to the tests specified in Section 9 (*a*). The remaining portion of the test specimen shall then have the exposed ends coated with a covering of rubber cement and be subjected to the digester test as specified in Section 10, after which another $2\frac{1}{2}$-in. portion shall be cut from the test specimen and subjected to the tests specified in Section 9 (*b*).

Tests of Tube and Cover.

8. (*a*) When the hose is less than 1 in. in diameter, the test specimens shall be cut longitudinally from the test sample. When the diameter is 1 in. or over, the specimen shall be cut transversely as prescribed by the "Standard Methods."

(*b*) The tensile strength of both the tube and the cover before steaming shall be not less than 600 lb. per sq. in.

(*c*) The tensile strength of both the tube and the cover after steaming shall be not less than 450 lb. per sq. in.

(*d*) The elongation at the breaking load for both the tube and the cover shall be such that the original 2-in. gage length of the test specimens shall stretch to not less than 6 nor more than 10 in. before steaming, and to not less than 4 nor more than 8 in. after steaming.

Friction Tests.

9. (*a*) The adhesive quality of the rubber friction binding the plies together shall be determined by suspending a 20-lb. weight from the separated end of a ply of a 1-in. test ring cut from the $2\frac{1}{2}$-in. sample described in Section 7, the force being applied radially. The rate of separation of the plies shall be not greater than 1 in. per minute. The test shall extend for 10 minutes when the size of the hose permits.

(*b*) The adhesive quality of the rubber friction after steaming shall be determined in the manner described in Section 9 (*a*), on a 1-in. test ring cut from the sample after it has been subjected to the digester test, except that a 15-lb. weight shall be used in place of the 20-lb. weight prescribed in Section 9 (*a*).

(*c*) The adhesion between the inner tube and cotton duck shall be the same as that between the plies.

Digester Test

10. The digester shall consist of a closed cylinder containing dry saturated steam at a pressure of 45 lb. per sq. in. The test specimen specified in Section 8 shall be placed in the digester and shall remain there for 48 hours continuously. An examination of the section after being subjected to the

heat of the steam should be made immediately after removal from the digester, and should disclose no blistering of the inner tube or loosening of the tube from the fabric. Tests after steaming prescribed in the specifications shall be made as soon as possible after the specimen has cooled for 24 hours.

III. SIZES AND DIMENSIONS.

Sizes and Dimensions.

11. (*a*) Steam hose shall be in accordance with the sizes and dimensions specified by the purchaser.

(*b*) The thickness of cover shall be not less than $\frac{1}{16}$ in. The thickness of tube shall be not less than $\frac{1}{8}$ in.

IV. MARKING.

Marking.

12. (*a*) Each 50-ft. length of hose shall have inlaid in rubber in three places, namely, midway between the ends and within 10 ft. of each end, a brand showing the name of the manufacturer, the month and year of manufacture, the trade name of the hose, and the legend "A.S.T.M. Specifications." Shorter lengths than 50 ft. shall have only one brand similar to the above inlaid in rubber.

(*b*) Serial numbers of rejected hose shall not be applied to any other hose during the same calender year.

V. INSPECTION AND REJECTION.

Inspection.

13. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the hose to permit of arrangement for inspection.

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the hose is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the hose in his own laboratory or elsewhere. But such tests shall be made within 60 days after receipt of the shipment and at the expense of the purchaser.

Rehearing.

14. Samples of rejected hose shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
RUBBER BELTING FOR POWER TRANSMISSION.[1]

Serial Designation: D 53 - 21 T.

These specifications are issued under the fixed designation D 53; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover two classes of rubber belting for power transmission:

(*a*) *Friction Covered.*—Possessing no distinct rubber cover other than that imparted to the cotton duck by the regular rubber frictioning process.

(*b*) *Rubber-Covered.*—Possessing a distinct rubber cover over the outside plies of rubber-frictioned cotton duck and extending around the edges.

I. MANUFACTURE.

Construction 2. The belting shall consist of:

(*a*) Cotton duck reinforcement;
(*b*) Rubber friction compound;
(*c*) An outside rubber cover, when specified.

Reinforcement. 3. The reinforcement shall consist of plies of cotton duck evenly and firmly woven, as free from such defects as foreign matter, knots, lumps and irregularities of twist as is consistent with the best manufacturing practice. Each ply shall be well frictioned on both sides with a rubber compound suitable for the required service.

Rubber Beading. 4. The seam in the outside ply of the belting shall be completely filled with a rubber cord, or "beading," well fastened down with a rubber cover-strip.

Rubber Cover. 5. When rubber-covered belting is specified, the rubber cover shall be uniform in thickness and free from cracks, blisters or other defects which would impair its moisture-resisting qualities.

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[1] These Tentative Specifications are in effect a revision of the Standard Specifications for Rubber Belting for Power Transmission. The Standard Specifications, which were last published under the Serial Designation D 53-20, have accordingly been withdrawn.

Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

II. PHYSICAL PROPERTIES AND TESTS.

Temperature of Testing Room and Samples.

6. Tests shall be made with the temperature of the air not lower than 65° F. or higher than 90° F., and the samples shall be kept at temperatures within these limits for at least 30 minutes previous to the time of test.

Sampling.

7. One sample, the full width of the belt, shall be taken from each lot of 500 ft. or less. This sample shall be 26 in. in length for all widths 6 in. and over, and 32 in. for widths under 6 in.

Number of Tests.

8. One friction test, one stretch test, one tension test, one beading test and three filler strength tests shall be made upon the sample described in Section 7.

Test Specimens.

9. Friction specimens may be taken either longitudinally or transversely of the sample of belting. Stretch and tension test specimens shall be the full width and thickness of the belting up to and including 5 in. For widths greater than 5 in. the test specimen shall be cut to a width of 5 in., parallel to an edge and beginning ½ in. from one of the edges of the belting.

Friction Test.

10. A strip 6 in. in length by 1 in. in width shall be cut from the sample and two specimens of two plies each shall be taken from this strip and tested separately as follows: The two plies of the specimen shall be separated at one end for a distance that will permit one ply to be placed in the top grip and the other in the bottom grip of the machine. The maximum pull in pounds required to separate the fabric for a distance of approximately 2 in. will be taken at three different points in that distance, and the average of the three readings taken on each of the two specimens will be considered as the friction, which shall be not less than 18 lb. This test shall be made with a machine speed of approximately 20 in. per minute.

Stretch Test of Belting.

11. A test specimen 20 in. in length and prepared as described in Section 9 shall have transverse reference lines marked upon it 10 in. apart and at equal distances from the ends; it shall then be tested in a tension testing machine and under a pull of 100 lb. per in. per ply, shall not stretch more than 7 per cent. The rate of separation of the jaws shall be approximately 1½ in. to 4 in. per minute.

Tension Test.

12. The stretch test described in Section 11 shall be continued to the breaking point in order to obtain the ultimate tensile strength which shall be not less than 260 lb. per in. per ply.

Test of Beading.

13. The beading in all belting 4 in. wide or over shall be tested as follows: A 4-in. transverse section of belting shall be taken and beginning on the seamless side, the plies shall be removed until three only remain intact. A line shall be drawn down the middle of the beading and then on each side of this line, and ⅝ in. distant from it,

two parallel lines shall be scribed. The section shall be inserted in a vise so that the jaws grip the sample coincident with the two outer lines. The vise shall be tightened until the inner surfaces of the doubled sample just touch at the top of the vise, and the sample shall be so held for 10 minutes. Under this test the beading shall not crack or loosen in the seam.

Test of Filler Strength of Duck.

14. The filler or weft strength of the cotton duck in the belting shall be determined as follows: A transverse strip $1\frac{1}{2}$ in. wide shall be cut from the belting and separated into its various plies. Three of these plies shall be ravelled down to a width of 1 in. and tested in a fabric testing machine, the minimum width of jaws of which is $1\frac{1}{2}$ in., the distance between jaws 3 in. and the speed of separation of jaws approximately 20 in. per minute. The tensile strength shall be at least 175 lb.

III. DIMENSIONS.

Width of Belting.

15. The width of the belting shall conform to that specified within the following tolerances:

WIDTH.	PERMISSIBLE PLUS OR MINUS VARIATIONS, IN.
Up to 12 in., inclusive	$\frac{3}{16}$
Over 12 in. to 24 in., inclusive	$\frac{1}{4}$
Over 24 in.	$\frac{5}{16}$

Thickness of Belting.

16. The thickness of the belting in inches shall be not less than 0.050 multiplied by the number of plies, plus the thickness of the rubber covers, if any.

Thickness of Cover.

17. The cover (Section 1 (*b*)) shall be not less than $\frac{3}{128}$ (=0.023) in. in thickness. This shall also apply to the edges.

IV. MARKING.

Marking.

18. Belting 4 in. wide or over shall have the name of the manufacturer, the month and year of manufacture, the trade name of the belt, and the legend "Power A.S.T.M. Specifications" impressed in the strip side at points not more than 15 ft. apart. For widths under 4 in. this information shall be stencilled on the belting.

Endless Belts.

19. Endless belts shall have marks showing in which direction the belt shall be run with regard to the splices.

V. INSPECTION AND REJECTION.

Inspection.

20. (*a*) The manufacturer shall notify the purchaser sufficiently in advance of the completion of the belting to permit of arrangement for inspection.

(*b*) The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the belting is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

(*c*) The purchaser may make the tests to govern the acceptance or rejection of the belting in his own laboratory or elsewhere. Such tests shall be made within 60 days after date of shipment at the expense of the purchaser.

Rehearing. 21. Samples of rejected belting shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
COMMERCIAL ADHESIVE TAPE FOR ELECTRICAL PURPOSES.[1]

Serial Designation: D 69 - 21 T.

These specifications are issued under the fixed designation D 69; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1920; REVISED, 1921.

Material Covered. 1. These specifications cover commercial adhesive tape (also called "friction" tape) consisting of strips of cotton sheeting impregnated with an adhesive insulating compound. The tape is largely used to cover electrical insulation applied to wires and cables.

I. MANUFACTURE.

Cotton Sheeting. 2. The cotton sheeting layer shall be made from a sheeting evenly and firmly woven from good cotton and as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with the best manufacturing practice. The threads shall run in as straight lines as possible without waving so as to reduce to a minimum the raveling of the cloth when cut into tape.

Frictioning Compound. 3. The frictioning compound shall be an adhesive and insulating compound practically free from free sulfur or other substances which would have a deteriorating effect on copper or other metals or on the fabric.

Impregnation of Fabric. 4. The fabric shall be thoroughly impregnated and evenly covered on both sides with the frictioning compound.

Adhesiveness of Compound. 5. The compound shall adhere firmly to the fabric and shall not pull away from the fabric so as to leave bare spots when adjacent layers of the tape are separated.

II. CHEMICAL PROPERTIES.

Sulfur. 6. The compound shall contain not more than 0.05 per cent of free sulfur.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

Discoloration of Copper. 7. When the tape is wrapped on a clean, bright, smooth copper rod and baked at 100° C. for 16 hours, the compound shall not discolor the copper.

III. PHYSICAL PROPERTIES AND TESTS.

Pin Holes. 8. When the tape is held before a strong light, the number of pin holes shall be determined in a length of not less than 3 yd. The number of pin holes shall not exceed the limits given in the following table:

WIDTH, IN.	MAXIMUM NUMBER IN 3 YD.	MAXIMUM NUMBER IN ANY SINGLE YD.
½	6	3
¾	6	3
1	9	4
1½	12	5
2	15	6

Tensile Strength. 9. The tensile strength of the tape shall be not less than 40 lb. per inch of width. The initial distance between the jaws of the testing machine shall be 12 in. and the rate of separation of the jaws shall be 20 in. per minute.

Friction. 10. (*a*) The adhesion between adjacent layers of the tape shall be such that when a strip of tape 2 ft. long is taken from a roll and wound upon a mandrel 1 in. in diameter under a tension of 10 lb. per inch of width at a rate of 30 in. per minute, a weight of 4 lb. per inch of width shall not cause the plies to separate at a rate greater than 30 in. per minute.

(*b*) After a strip has been exposed to dry air at a temperature of 100° C. for 16 hours and then cooled to room temperature, a test specimen shall withstand the test prescribed in Paragraph (*a*) except that the weight applied to unwind the tape shall be 1⅓ lb. per in. of width instead of 4 lb.

Dielectric Strength. 11. The test for dielectric strength shall be made as follows: The tape shall be spirally wound with one-third lap on a smooth metal rod, 1 in. in diameter, for a distance of 6 in. Two inches in the center shall be covered with metal foil and securely bound with tape. Alternating potential of 1000 volts (r.m.s. value) and having a frequency not exceeding 65 cycles per second shall be applied for five minutes to the metal rod and the metal foil without puncturing the tape.

Test Samples. 12. One roll for each 250 rolls shall be taken at random for test. At least 2 ft. of the outer layers shall be removed and discarded before taking specimens for test.

IV. STANDARD WEIGHT, DIMENSIONS AND VARIATIONS.

Weights, Dimensions and Yardage.

13. The tape shall conform to the following requirements:

WIDTH, IN.	THICKNESS, IN.	NOMINAL WEIGHT PER ROLL, LB.	MINIMUM NET WEIGHT PER 100 ROLLS, LB.[a]	MINIMUM LENGTH PER POUND YD.[a]
½	0.015	¼	25	82
¾	0.015	½	50	55
1	0.015	½	50	41
1½	0.015	1 or 1¼	100 or 125	27
2	0.015	1½	150	20

[a] Exclusive of core, wrapping and box.

Measurement of Thickness.

14. The thickness shall be measured with a micrometer graduated to 0.001 in., having a circular foot, 0.24 to 0.26 in. in diameter and with a pressure on the specimen of not less than 8 oz. nor more than 10 oz. Five measurements shall be made at random in a length of not less than 3 ft. and no result shall be outside the limits prescribed.

Permissible Variations.

15. The width shall not vary from the specified value by more than $\frac{1}{32}$ in. The thickness shall not vary from the specified value by more than 0.002 in.

V. PACKING AND MARKING.

Packing.

16. Each roll shall be wrapped in paraffined paper or metal foil and enclosed in a suitable box. The wrapping shall be secure and shall thoroughly protect the contents.

Marking.

17. Each box shall be marked with the name of the manufacturer or a trade mark together with the nominal width and weight of the tape.

VI. INSPECTION AND REJECTION.

Time of Inspection.

18. The tape shall be inspected and tested within four weeks from the date of delivery.

Retests and Rejections.

19. If the tape fails in any one test of those prescribed in these specifications, two additional specimens will be taken and submitted to that test. If either of these two additional specimens fails, the lot of tape represented by that sample shall be rejected.

TENTATIVE SPECIFICATIONS
FOR
RUBBER INSULATING TAPE.[1]

Serial Designation: D 119 – 21 T.

These specifications are issued under the fixed designation D 119; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Material Covered. 1. These specifications cover rubber insulating tape to be used for insulating joints in electric wires and cables.

I. MANUFACTURE.

Compound. 2. The tape shall be a rubber compound which shall be well, evenly and smoothly calendered, cut to uniform width and tightly wound in rolls with a glazed cloth, parchment paper or a linen separator interposed between adjacent layers.

Separator. 3. The separator shall be attached to and cover the outer side of the tape. When unwound from the original roll, it shall show no undue tendency to stick to the rubber.

II. CHEMICAL PROPERTIES AND TESTS.

Composition. 4. The tape shall be a rubber compound containing not less than 30 per cent of the best quality Hevea rubber, not more than one per cent of free sulfur and not more than 4 per cent of waxy hydrocarbons.

The remainder shall consist only of suitable dry inorganic mineral fillers. The compound shall contain no reclaimed rubber, substitutes or organic matter other than herein above specified. All percentages shall be based on the weight of the original compound.

Chemical Analysis. 5. If an analysis of the compound is made, it shall be carried out in accordance with the Joint Rubber Insulation Committee's procedure (see Appendix II to the Tentative Specification for Insulated Wire and Cable: 30-Per-Cent Hevea Rubber (Serial Designation: D 27 – 21 T) of the American Society for Testing Materials).[2]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 850, 466 Lexington Ave., New York City.

[2] See p. 746.

III. PHYSICAL PROPERTIES AND TESTS.

Tensile Strength. 6. (*a*) The tensile strength of the tape shall be not less than 300 lb. per sq. in.

(*b*) The tests shall be made with a power driven, pendulum-type tension testing machine; the initial distance between the jaws shall be 3 in. and the rate of separation of the jaws shall be 20 in. per minute. The width of the test specimen shall be 0.5 in.

(*c*) Three specimens of each sample free from visible flaws shall be tested. The average result shall be taken as the tensile strength.

(*d*) The temperature of the room shall be not lower than 65° F. (18° C.) nor higher than 90° F. (32° C.) and the samples shall have been kept within these temperature limits for at least 30 minutes previous to the time of testing.

Dielectric Strength. 7. Two brass-ball sphere electrodes 2 cm. in diameter shall be brought so close together that the sample of tape can be just moved between them. The tape shall withstand without puncturing the application of a potential of 10,000 volts (r.m.s. value) for a period of five minutes applied to the sphere electrodes at a frequency not exceeding 65 cycles per second.

Fusion. 8. The tape when wrapped to a thickness of ¼ in. and heated to a temperature of 150° F. (65°.5 C.) for 20 minutes shall fuse into a homogeneous mass.

Test Samples. 9. One roll for each 250 rolls shall be taken at random for test. At least 2 ft. of the outer layers shall be removed and discarded before taking specimens for test.

IV. STANDARD WEIGHTS, DIMENSIONS AND VARIATIONS.

Thickness, Weight and Yardage. 10. The tape shall conform to the following requirements:

Width, in.	Thickness, in.	Nominal Weight per Roll, lb.	Minimum Net Weight per 100 Rolls, lb.[a]	Minimum Length per Pound, Yd.[b]
½	0.035	½	50	22½
¾	0.035	½	50	15
1	0.035	1	100	11¼

[a] Exclusive of core, wrapping and box.

[b] Exclusive of core, wrapping, box and separator.

Permissible Variations. 11. The width shall not vary from the specified value by more than $\frac{1}{32}$ in. The thickness shall not vary from the specified value by more than 0.003 in.

Measurement of Thickness. 12. The thickness shall be measured with a micrometer graduated to 0.001 in. having a circular foot, 0.24 to 0.26 in. in diameter, and with a pressure on the specimen of not less than 8 oz. or more than 10 oz. Four measurements shall be made at random in a length of not less than 3 ft. and no measurement shall be outside the limits prescribed in Sections 10 and 11.

V. PACKING AND MARKING.

Packing. 13. Each roll shall be wrapped in paraffined paper or metal foil and enclosed in a suitable box. The wrapping shall be secure and shall thoroughly protect the contents.

Marking. 14. Each box shall be marked with the name of the manufacturer or trade mark and the nominal width and weight of the tape.

VI. INSPECTION AND REJECTION.

Time of Inspection. 15. The tape shall be tested and inspected within four weeks of the date of delivery.

Retest and Rejection. 16. If the tape fails in any one test of those prescribed in these specifications, two additional specimens shall be taken and submitted to that test. If either of these two additional specimens fails, the lot of tape represented by that sample roll shall be rejected.

TENTATIVE SPECIFICATIONS
FOR
RUBBER GLOVES FOR ELECTRICAL WORKERS ON APPARATUS OR CIRCUITS NOT EXCEEDING 3000 VOLTS TO GROUND.[1]

Serial Designation: D 120 – 21 T.

These specifications are issued under the fixed designation D 120; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

SPECIFICATIONS.

Material Covered. 1. These specifications cover electrical workers' rubber gloves of two classes:

Class A.—Gloves intended for use without external protection.

Class B.—Gloves intended for use with external protection of leather or other material.

I. MANUFACTURE.

Process. 2. The gloves shall be made by the "dipping" process, of high-grade rubber or rubber compound properly vulcanized, and shall be reversible. Unless otherwise specified cuff edges shall be finished with a roll.

II. PHYSICAL PROPERTIES AND TESTS.

Methods. 3. All tests shall be made in accordance with the methods described in Sections 15–26 inclusive.

(*A*) *Electrical.*

Voltage and Leakage Tests. 4. (*a*) Each glove shall withstand an alternating potential of 10,000 volts (r.m.s. value) for three minutes without showing a leakage current of more than 10 milliamperes at any time during the test.

(*b*) Each glove shall be capable of withstanding the application of the following voltage (r.m.s. value) for one minute without showing a leakage current in excess of that given below:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. C. B. Martin, Secretary of Committee D-11 on Rubber Products, Room 350, 466 Lexington Ave., New York City.

	VOLTS.	MILLIAMPERES.
Class A	16 000	18
Class B	14 000	14

(*B*) *Mechanical.*

Tensile Strength, Elongation and Set.

5. A standard test specimen cut from any glove shall have the following physical properties:

(*a*) The tensile strength shall be not less than 1200 lb. per sq. in.

(*b*) The total elongation at rupture shall be not less than 500 per cent in 2 in. (2 in. stretched to 12 in.).

(*c*) The set following a stretch from 2 to 12 in., shall not exceed 0.7 in.

III. STANDARD SIZES AND DIMENSIONS.

Size and Length.

6. (*a*) The size of each glove shall be as specified subject to a permissible variation of $\pm\frac{1}{4}$ in. and shall be expressed in inches as measured around the palm at the base of knuckles.

(*b*) Unless otherwise specified the length of each glove from the tip of the second finger to the edge of cuff, shall be 14 in. subject to a permissible variation of $\pm\frac{1}{2}$ in.

Thickness.

7. The respective thicknesses of the two classes of gloves in inches shall be within the following limits:

	PART OF GLOVE OTHER THAN CROTCH.		CROTCH.	
	MAXIMUM.	MINIMUM.	MAXIMUM.	MINIMUM.
Class A	0.065	0.050	0.065	0.038
Class B	0.050	0.030	0.050	0.022

IV. WORKMANSHIP AND FINISH.

Surface Defects.

8. Gloves shall be free from patches, blisters, pinholes, cracks, protuberances, embedded foreign matter or other physical defects which can be detected by thorough surface inspection.

V. MARKING AND PACKING.

Marking.

9. Unless otherwise specified each glove shall be marked with the manufacturer's name and the size of glove. Such marking shall be confined to the cuff of the glove and shall be so done as not to injure the glove.

Packing.

10. Each pair of gloves shall be packed in an individual stiff paper box of sufficient strength to properly protect the gloves. The end of the box shall be marked with the glove size and in the case of Class B gloves with the words "For use with Protectors."

VI. GUARANTEE.

Guarantee.

11. The manufacturer shall replace, without cost to the purchaser, gloves which at any time within a period of eight months from the

date of initial test, fail to pass the tests herein prescribed; provided the gloves have been stored in their original boxes at a temperature not exceeding 75° F.

VII. INSPECTION AND REJECTION.

Place and Time of Tests.

12. Inspection and test unless otherwise specified shall be made within two weeks of receipt by the purchaser at his own expense at such place as he may designate.

Rejections.

13. (*a*) Each glove that fails to meet the requirements of Sections 4 (*a*) or 8 shall be rejected. In the case of gloves failing to meet the requirements of Sections 6, 9 and 10 rejection is optional with the purchaser.

(*b*) If any of the measurements of thickness made as prescribed in Section 16 or any additional measurements which the purchaser may elect to make fall below the minimum thickness specified in Section 7, the glove shall be rejected. If any of the measurements exceed the maximum thickness specified, rejection is optional with the purchaser.

(*c*) If rejections under Paragraphs (*a*) and (*b*) exceed 25 per cent of the shipment the whole shipment may be rejected without further tests.

(*d*) If 50 per cent or more of the gloves subjected to the test prescribed in Section 4 (*b*) fail to pass the test, the entire shipment shall be rejected.

(*e*) If the average of the results for either the tensile strength, elongation or set tests made as prescribed in Section 26 fail to meet the requirements of Section 5, the entire shipment shall be rejected.

Marking Rejected Gloves.

14. All rejected material shall be returned to the manufacturer without being defaced by rubber stamp or other permanent marking, excepting gloves which have been punctured on electrical tests. These shall be stamped, punched or cut to indicate that they are unfit for electrical use.

METHODS OF TEST.

Order of Procedure.

15. The order of procedure in testing rubber gloves shall preferably be as follows:[1]

(*a*) Inspection of inside and outside surfaces (see Section 8).
(*b*) Measurement of length (see Section 6 (*b*)).
(*c*) Measurement of size (see Section 6 (*a*)).

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[1] This procedure has been found by experience to minimize the expense of the inspection and testing, particularly where an appreciable number of gloves fail to meet the requirements as to workmanship or dimensions.

(*d*) Measurement of thickness (see Section 7).

(*e*) Electrical test (see Section 4 (*a*)).

(*f*) Dielectric strength (see Section 4 (*b*)).

(*g*) Mechanical test (see Section 5).

VIII. DIMENSIONS.

Thickness.

16. (*a*) The thickness of each glove shall be measured at not less than four points on the face and four points on the back.

(*b*) Measurements shall be made at one or more points in the crotch of thumb and index finger.

(*c*) These measurements shall be made with any micrometer graduated to mils or tenths of mils having a ratchet friction or spring attachment. The tension on the friction attachment should be so adjusted that when the anvil has come to a stop, the specimen can be moved between the spindle and anvil without causing any appreciable stretching of the rubber. A spring rubber gage is particularly well suited to measurements in face and back of glove.

IX. ELECTRICAL TESTS.

Leakage.

17. Each glove shall be tested for leakage in fresh water at normal room temperature (60 to 80° F.) by immersing in the water to within about $1\frac{1}{2}$ to 2 in. of the edge of the cuff and filling with water up to the same point. The water inside the glove and that outside the glove form the test electrodes. These are conveniently connected to the testing transformer by means of a chain suspended in the glove and by direct connection to the containing vessel.

Source of Test Voltage.

18. The testing voltage shall be obtained from a testing equipment, no part of which has a rating at the testing voltage of less than $\frac{1}{2}$ kva. per glove being tested. In no case shall the rating of any part of the testing apparatus be less than 2 kva. The frequency of the testing voltage shall be not more than 65 cycles.

Application of Test Voltage.

19. The potential shall be applied at a low value and gradually and steadily raised at a rate of approximately 800 to 1000 volts per second until the prescribed testing voltage is reached.

Test Period.

20. The test period shall be counted from the instant when the prescribed testing voltage is reached.

Voltage Regulation.

21. The method of regulating the testing voltage shall be one which does not distort the wave form of the testing voltage from a sine wave. Acceptable methods include:

(*a*) Field regulation of the alternator supplying the transformer;

(*b*) Induction-type regulator;

(*c*) Variable-ratio-transformer type of regulator;

(*d*) Potentiometer type of rheostatic control where the current in the portion of the "potentiometer" resistance in parallel with the primary of the transformer is at least five times the exciting current of the transformer.

Voltage Measurement. 22. The testing voltage shall be measured by one of the following methods:

(*a*) A properly calibrated electrostatic voltmeter connected directly across the gloves under test.

(*b*) Any properly calibrated commercial type of alternating voltmeter connected to the low tension side of the transformer in conjunction with the ratio of transformation of the transformer provided that the ratio is definitely known for all test conditions.

(*c*) A calibrated potential transformer with a voltmeter.

Leakage Current Measurement. 23. The leakage current shall be measured by one of the following methods:

(*a*) Directly, by inserting a milliammeter in series with each individual glove in turn.

NOTE.—It is customary to make high voltage tests of this character with one end of the circuit grounded, the containing vessel usually being the grounded end of the circuit. The milliammeter should therefore be connected in at the grounded end of the circuit and shunted by a short circuiting automatic self-closing switch which will therefore always keep the circuit closed except at the instant of reading and thus maintaining an uninterrupted ground.

(*b*) An ammeter in the low tension circuit of the testing transformer. In this case the leakage current should be determined by noting the decrease in the low tension current when the glove is disconnected from the high tension testing circuit, the voltage being left on the test circuits. The difference in the two currents divided by the ratio will give the leakage current with sufficient accuracy. If several gloves are tested at any one time, the leakage current may be determined by noting the decrease in the low tension current when one glove at a time is disconnected from the test circuit, the remaining gloves being left connected to the circuit.

Dielectric Strength Test. 24. (*a*) One per cent of the gloves (in no case less than two gloves) which have passed all the tests previously prescribed herein shall be selected at random and tested for compliance with Section 4 (*b*) and also for ultimate dielectric strength. The tests shall be made in accordance with the general method described in Sections 17 to 23 inclusive. If the glove passes the test prescribed in 4 (*b*), the potential shall be raised steadily and gradually at a rate of approximately 1000 volts per second until failure occurs, the voltage at failure being recorded.

(*b*) If any glove fails to meet the requirements of Section 4 (*b*), an additional glove shall be selected at random and tested.

X. MECHANICAL TESTS.

Test Specimens.

25. Four or more standard test specimens shall be cut from each glove tested under Section 24. The shape of these specimens shall be in substantial accordance with that prescribed in Section 20 of the Standard Methods of Testing Rubber-Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1] The essential dimensions of this sample are:

Total length: 6 in.

Width: 1¼ in. with a reduced section at the center, ½ in. wide and about 2½ in. long with radii of curvature between the ends and reduced section of ⅞ in.

Tensile Strength, Elongation and Set.

26. The tests for tensile strength, elongation and set shall be made in accordance with Sections 19, 22, 23, 24, and 25 of the Standard Methods of Testing Rubber Lined Hose (Serial Designation: D 15) of the American Society for Testing Materials.[1] The essential features of these sections are:

(*a*) Temperature of testing room and of specimens, between 65 and 90° F.

(*b*) Rate of separation of jaws of testing machine, 20 in. per minute.

(*c*) Tensile strength and elongation shall be made on one sample and set test on a separate sample.

(*d*) Set test shall be made by stretching the 2-in. gage length to 12 in., holding for ten minutes and measuring the distance between the bench marks 10 minutes after release.

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[1] 1921 Book of A.S.T.M. Standards.

TENTATIVE SPECIFICATIONS
FOR
IMPERFECTIONS AND TOLERANCES FOR 60-IN. 17¼-OZ. SQUARE-WOVEN TIRE BUILDER FABRIC.[1]

Serial Designation: D 122 – 21 T.

These specifications are issued under the fixed designation D 122; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

IMPERFECTIONS.

Definition.

1. Imperfections shall be those defects in material and workmanship which are in large measure capable of reduction and control by supervision and which, though important, do not form an essential element of the specifications. They may be classified as such deviations from the qualitative characteristics of the perfect fabric as shall materially depreciate its commercial value.

Misweaves.

2. The following imperfections are to be classified as misweaves: mispicks, double picks, floats, broken picks and ends, dropped threads, wrong draws, filling cuts, reed marks, light and heavy strips, smash.

(*a*) Heavy strip is a place in the fabric which contains more than the specified number of picks per inch.

(*b*) Thin strip is a place in the fabric which contains less than the specified number of picks per inch.

(*c*) Reed mark in the fabric is caused by a sprung reed in the loom during weaving and appears in the fabric as though two warp threads had been forced apart with the result that the next threads are very close together.

(*d*) Wrong draw is caused by drawing warp threads through wrong harness and appears in the fabric as a streak lengthwise due to the filling floating over more than one thread.

(*e*) A mispick is a missing or partly missing pick and appears as a streak across the width of the fabric.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to Mr. G. W. Skirm, Secretary of Committee D-13 on Textile Materials, United and Globe Rubber Co., Trenton, N. J.

Deductions. 3. Misweaves may be sufficient cause for deductions if the fabric is weakened thereby either as it is or in later processes, unless the misweave is satisfactorily repaired.

Rejections. 4. Misweaves are sufficient cause for rejection of a roll if they are of such extent, importance and frequency as to require cutting the fabric in four or more places per 100 yd.

Imperfect Selvage. 5. Tight, loose, cut, weak and nicked or wavy selvage may be considered imperfect selvage.

Deductions. 6. Imperfect selvage may be cause for deductions if it is sufficiently imperfect to cause trouble or waste of material in processing.

Rejection. 7. Imperfect selvage may be sufficient cause for rejection if its extent, frequency and importance requires cutting of the fabric in four or more places per 100 yd.

Knots. 8. No knots are allowable in the ply yarn except in colored identification threads and in selvage.

Deductions. 9. Knots in the ply yarn may be cause for deductions. An allowance of one-quarter per knot is suggested.

Rejections. 10. Knots in the ply yarn may be sufficient cause for rejection if they occur in excess of 25 knots per 100 yds. of the fabric.

Broken Threads. 11. All broken threads should be properly repaired.

Deductions. 12. Broken threads although repaired may be sufficient cause for deductions if they cause reduction of strength below the tolerance for individual tests or cause waste of material.

Rejections. 13. Broken threads may be sufficient cause for rejection of a roll, if they are of such extent, frequency, and importance as to require cutting the fabric in four or more places per 100 yd.

Oil Spots. 14. Oil spots or oily yarn should be reduced to the smallest possible number and if present should be thoroughly removed.

Deductions. 15. Oil spots or oily yarn may be cause for deduction if of sufficient size to require the cutting and waste of fabric.

Rejections. 16. Oil spots or oily yarn may be sufficient cause for rejection of a roll if they are of such extent, frequency and importance as to require the cutting of the fabric in four or more places per 100 yd.

TOLERANCES.

Definition. 17. Tolerances shall be the limits within which a textile must come in its specified characteristics in order that it shall constitute a good delivery on contract. They may be classified as the allowable limits of the quantitative characteristics of the fabric as defined in the specifications. The following tolerances are based upon the Standard General Methods of Testing Cotton Fabrics (Serial Designation: D 39) of the American Society for Testing Materials.[1]

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[1] 1921 Book of A.S.T.M. Standards.

18. (*a*) No individual measurement made to determine the width of the fabric shall be more than 2 per cent over or one per cent under the specified average width. **Width.**

(*b*) The average width determined by measurements shall be not more than one per cent over nor 0.5 per cent under the specified average width.

19. The weight of the fabric determined by test shall be not more than 1.5 per cent under nor more than 3 per cent over the specified weight. **Weight per Square Yard.**

20. The count per inch determined by test shall be not more than 0.2 ends over nor 0.4 ends under the specified count and not more than one pick over or under for the filler. **Count per Inch.**

21. The bow determined by test shall be not more than ¼ in. over or under the bow specified. **Bow.**

NOTE.—Bow should be ascertained by five determinations made throughout the roll commencing at least 10 yd. from either end of roll.

22. The allowable variation in the off-square of the fabric shall be 3 per cent over or under the specified off-square. **Off-square.**

23. (*a*) The individual measurements of the thickness shall not vary more than 0.005 in. under or over the specified thickness. **Gage.**

(*b*) The average thickness determined by test shall not vary more than 0.002 in. under nor 0.003 in. over the specified thickness.

24. Individual test results on warp and filling shall be not more than 5 per cent below the specified tensile strength. The average tensile strength of the warp and the average tensile strength of the filling found by test shall be not less than the specified tensile strength. **Tensile Strength.**

TENTATIVE DEFINITIONS OF TERMS RELATING TO MECHANICAL FABRIC.[1]

Serial Designation: D 123 - 21 T.

These definitions are issued under the fixed designation D 123; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

1. The term "Mechanical Fabric" shall be understood to mean fabric manufactured to be used as an intermediate product in the making of some mechanically constructed article.

2. Mechanical fabrics shall be referred to by the following descriptive nomenclature:

(*a*) A word or phrase generally descriptive of the appearance of the material, or the use to which it is put.

(*b*) Weight in ounces per square yard. The words "oz. sq. yd." are to be written after the weight. To avoid confusion in regard to weight of material, it is suggested that immediately succeeding the square yard weight, the weight of the material on whatever basis may have been used previous to the adoption of these standards be inserted in brackets. Table I gives the conversion values of linear yard weight to square yard weight.

(*c*) Width in inches.

(*d*) Count, giving first the ends, and second the picks per inch.

Example: Hose Duck, 9 oz. sq. yd. [40 in. 10 oz.], 48 in., 28 by 18.

3. The following is a partial list of mechanical fabrics in general use:

Tire Builder Fabric.—A square woven fabric having usually 11-ply yarn in both warp and filling.

Tire Cord Fabric.—A fabric consisting of hawser cord yarn in the warp, with single yarn filling at intervals to keep warp threads together.

Hose Duck.—A soft, plain-weave duck of plied yarns not finer than No. 8, made in weights from 10 to 24 oz. to the 40-in. width. When made of finer yarn than No. 8, it is classed as Special Hose Duck.

Rubber Belt Duck.—A soft, plain-weave duck of plied yarns not finer than No. 8, weight ranging from 22 to 36 oz. to 42-in. width.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr. G. W. Skirm, Secretary of Committee D-13 on Textile Materials, United and Globe Rubber Co., Trenton, N. J.

TABLE I.—CONVERSION TABLE OF LINEAR YARD WEIGHT TO SQUARE YARD WEIGHT OF FABRIC.

Weight, oz.	Width, in.																														
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
8......	9.60	9.29	9.00	8.73	8.47	8.23	8.00	7.78	7.58	7.38	7.20	7.02	6.86	6.70	6.55	6.40	6.26	6.13	6.00	5.88	5.76	5.65	5.54	5.43	5.33	5.24	5.14	5.05	4.97	4.88	4.80
9......	10.80	10.45	10.13	9.82	9.53	9.26	9.00	8.76	8.53	8.31	8.10	7.90	7.71	7.53	7.36	7.20	7.04	6.89	6.75	6.61	6.48	6.35	6.23	6.11	6.00	5.89	5.79	5.68	5.59	5.49	5.40
10......	12.00	11.61	11.25	10.91	10.59	10.29	10.00	9.73	9.47	9.23	9.00	8.78	8.57	8.37	8.18	8.00	7.83	7.66	7.50	7.35	7.20	7.06	6.92	6.79	6.67	6.55	6.43	6.32	6.21	6.10	6.00
11......	13.20	12.77	12.38	12.00	11.65	11.31	11.00	10.70	10.42	10.15	9.90	9.66	9.43	9.21	9.00	8.80	8.61	8.43	8.25	8.08	7.92	7.76	7.62	7.47	7.33	7.20	7.07	6.95	6.83	6.71	6.60
12......	14.40	13.94	13.50	13.09	12.71	12.34	12.00	11.68	11.37	11.08	10.80	10.54	10.29	10.05	9.82	9.60	9.39	9.19	9.00	8.82	8.64	8.47	8.31	8.15	8.00	7.85	7.71	7.58	7.45	7.32	7.20
13......	15.60	15.10	14.63	14.18	13.76	13.37	13.00	12.65	12.32	12.00	11.70	11.41	11.14	10.88	10.64	10.40	10.17	9.96	9.75	9.55	9.36	9.18	9.00	8.83	8.67	8.51	8.36	8.21	8.07	7.93	7.80
14......	16.80	16.26	15.75	15.27	14.82	14.40	14.00	13.62	13.26	12.92	12.60	12.29	12.00	11.72	11.45	11.20	10.96	10.72	10.50	10.29	10.08	9.88	9.69	9.51	9.33	9.16	9.00	8.84	8.69	8.54	8.40
15......	18.00	17.42	16.88	16.36	15.88	15.43	15.00	14.60	14.21	13.85	13.50	13.17	12.86	12.56	12.27	12.00	11.74	11.49	11.25	11.02	10.80	10.59	10.38	10.19	10.00	9.82	9.64	9.47	9.31	9.15	9.00
16......	19.20	18.58	18.00	17.45	16.94	16.46	16.00	15.57	15.16	14.77	14.40	14.05	13.71	13.40	13.09	12.80	12.52	12.26	12.00	11.76	11.52	11.29	11.08	10.87	10.67	10.47	10.29	10.11	9.93	9.76	9.60
17......	20.40	19.74	19.13	18.56	18.00	17.49	17.00	16.54	16.11	15.69	15.30	14.93	14.57	14.23	13.91	13.60	13.30	13.02	12.75	12.49	12.24	12.00	11.77	11.55	11.33	11.13	10.93	10.74	10.55	10.37	10.20
18......	21.60	20.90	20.25	19.64	19.06	18.51	18.00	17.51	17.05	16.62	16.20	15.80	15.43	15.07	14.73	14.40	14.09	13.79	13.50	13.22	12.96	12.71	12.46	12.23	12.00	11.78	11.57	11.37	11.17	10.98	10.80
19......	22.80	22.06	21.38	20.73	20.12	19.54	19.00	18.49	18.10	17.54	17.10	16.68	16.29	15.91	15.55	15.20	14.87	14.55	14.25	13.96	13.68	13.41	13.15	12.91	12.67	12.44	12.21	12.00	11.79	11.59	11.40
20......	24.00	23.23	22.50	21.82	21.18	20.57	20.00	19.46	18.95	18.46	18.00	17.56	17.14	16.74	16.36	16.00	15.65	15.32	15.00	14.69	14.40	14.12	13.85	13.58	13.33	13.09	12.86	12.63	12.41	12.20	12.00
21......	25.20	24.39	23.63	22.91	22.24	21.60	21.00	20.43	19.89	19.38	18.90	18.44	18.00	17.58	17.18	16.80	16.43	16.09	15.75	15.43	15.12	14.82	14.54	14.26	14.00	13.75	13.50	13.26	13.03	12.81	12.60
22......	26.40	25.55	24.75	24.00	23.29	22.63	22.00	21.41	20.84	20.31	19.80	19.32	18.86	18.42	18.00	17.60	17.22	16.85	16.50	16.16	15.84	15.53	15.23	14.94	14.67	14.40	14.14	13.89	13.66	13.42	13.20
23......	27.60	26.71	25.88	25.09	24.35	23.66	23.00	22.38	21.79	22.23	20.70	20.20	19.71	19.26	18.82	18.40	18.00	17.62	17.25	16.89	16.56	16.24	15.92	15.62	15.33	15.05	14.79	14.53	14.28	14.03	13.80
24......	28.80	27.87	27.00	26.18	25.41	24.69	24.00	23.35	22.74	22.15	21.60	21.07	20.57	20.09	19.64	19.20	18.78	18.38	18.00	17.63	17.28	16.94	16.62	16.30	16.00	15.71	15.43	15.16	14.90	14.64	14.40
25......	30.00	29.03	28.13	27.27	26.47	25.71	25.00	24.33	23.68	23.08	22.50	21.95	21.43	20.93	20.45	20.00	19.57	19.15	18.75	18.37	18.00	17.65	17.31	16.98	16.67	16.36	16.07	15.79	15.52	15.25	15.00
26......	31.20	30.19	29.25	28.36	27.53	26.74	26.00	25.30	24.63	24.00	23.40	22.83	22.29	21.77	21.27	20.80	20.35	19.91	19.50	19.10	18.72	18.35	18.00	17.66	17.33	17.02	16.71	16.42	16.14	15.86	15.60
27......	32.40	31.35	30.38	29.45	28.59	27.77	27.00	26.27	25.58	24.92	24.30	23.71	23.14	22.60	22.09	21.60	21.13	20.68	20.25	19.84	19.44	19.06	18.69	18.34	18.00	17.67	17.36	17.05	16.76	16.47	16.20
28......	33.60	32.52	31.50	30.55	29.65	28.80	28.00	27.25	26.53	25.85	25.20	24.59	24.00	23.44	22.91	22.40	21.91	21.45	21.00	20.57	20.16	19.76	19.38	19.02	18.67	18.33	18.00	17.68	17.38	17.08	16.80
29......	34.80	33.68	32.63	31.64	30.71	29.83	29.00	28.22	27.47	26.77	26.10	25.46	24.86	24.28	23.73	23.20	22.70	22.21	21.75	21.31	20.88	20.47	20.08	19.70	19.33	18.98	18.64	18.32	18.00	17.69	17.40
30......	36.00	34.84	33.75	32.73	31.76	30.85	30.00	29.19	28.42	27.69	27.00	26.34	25.71	25.12	24.55	24.00	23.48	22.98	22.50	22.04	21.60	21.18	20.77	20.37	20.00	19.64	19.29	18.95	18.62	18.31	18.00
31......	37.20	36.00	34.88	33.82	32.82	31.89	31.00	30.16	29.37	28.62	27.90	27.22	26.57	25.95	25.36	24.80	24.26	23.74	23.25	22.78	22.32	21.88	21.46	21.06	20.67	20.29	19.93	19.58	19.24	18.92	18.60
32......	38.40	37.16	36.00	34.91	33.88	32.91	32.00	31.14	30.32	29.54	28.80	28.10	27.43	26.79	26.18	25.60	25.04	24.51	24.00	23.51	23.04	22.59	22.15	21.74	21.33	20.95	20.57	20.21	19.86	19.53	19.20
33......	39.60	38.32	37.13	36.00	34.94	33.94	33.00	32.11	31.26	30.46	29.70	28.98	28.29	27.63	27.00	26.40	25.83	25.28	24.75	24.24	23.76	23.29	22.85	22.42	22.00	21.60	21.21	20.84	20.48	20.14	19.80
34......	40.80	39.48	38.25	37.09	36.00	34.97	34.00	33.08	32.21	31.38	30.60	29.85	29.14	28.47	27.82	27.20	26.61	26.04	25.50	24.98	24.48	24.00	23.54	23.09	22.67	22.25	21.86	21.47	21.10	20.75	20.40
35......	42.00	40.65	39.38	38.18	37.06	36.00	35.00	34.06	33.16	32.31	31.50	30.73	30.00	29.30	28.64	28.00	27.39	26.81	26.25	25.71	25.20	24.71	24.23	23.77	23.33	22.91	22.50	22.11	21.72	21.35	21.00
36......	43.20	41.81	40.50	39.27	38.12	37.03	36.00	35.03	34.11	33.23	32.40	31.61	30.86	30.14	29.45	28.80	28.17	27.57	27.00	26.45	25.92	25.41	24.92	24.45	24.00	23.56	23.14	22.74	22.34	21.97	21.60

When made of finer yarn than No. 8, it is classed as Special Belt Duck.

Balata Belt Duck.—A closely woven fabric made of hard twisted plied yarn usually made in wide widths, weight being based on the square yard.

Oil Belt Duck.—A closely woven fabric of plied yarns not over No. 8, made in a variety of widths, the weight being based on the square yard.

Numbered Duck.—A plain woven fabric of plied yarns ranging from coarse to fine numbers, weight being based on 22-in. width one yard long.

Army Duck.—A fabric made in closely woven plied yarns weight being based on 28½-in. width.

Single Filled or Flat Duck.—A fabric made of single yarn, plain weave, the weight being based on 30-in. width.

Enameling Duck.—A plain woven fabric with laid warp and plied yarn filling, weight being based on 46½-in. width.

TENTATIVE METHODS
OF
METALLOGRAPHIC TESTING OF IRON AND STEEL.[1]

Serial Designation: E 3 – 21 T.

These methods are issued under the fixed designation E 3; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

MACROSCOPIC EXAMINATION.

PREPARATION OF SURFACE.

In order to show up both chemical and crystalline heterogeneity, sections of iron and steel are more or less deeply etched in order to bring out their macrostructure. In this way the persistence of the dendritic structure of castings even after much heat treatment and mechanical working, physical unsoundness such as blowholes, gas cavities, porosity, fine internal cracks and flakes, discontinuities of structure such as found in welding, flow of metal as in riveting, punching, hot pressing and forging, etc., are brought out.

Suitable sections are cut, smoothed and then ground on various grades of emery paper in order to obtain a smooth flat surface. In some cases it is necessary to continue polishing through No. 0. and No. 00. French Emery Papers. The sample ought to have a surface free from grease and dirt; if necessary it is then freed from all grease by cleaning with gasoline and then alcohol when it is ready for immersion in the solution.[2]

SOLUTIONS USED IN ETCHING.

Macroscopic etching of iron and steel was used as early as 1783 by Bergman. Many different solutions have been used and many of them are given by Campbell,[3] and more recently by Rawdon.[4]

Of the following solutions 1 (*a*) and 2 are recommended.

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[1] Criticisms of these Tentative Methods are solicited and should be directed, preferably before January 1, 1922, to Mr. G. F. Comstock, Secretary of Committee E-4 on Metallography, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.

[2] For large sections various methods have been devised depending on the material. Surface grinding when carefully done gives excellent results.

[3] *Proceedings*, Am. Soc. Test. Mats., Vol. XV, Part II, p. 96 (1915).

[4] The Structure and Related Properties of Metals. Bureau of Standards Circular. (In the press.)

1. To show up segregation and the like:

(*a*) Hot concentrated hydrochloric acid used at about 100° C. A deep etched specimen may be printed with printer's ink.

(*b*) Etching for 4 to 5 hours with 5-per-cent picric acid in alcohol.

2. To show up variations in crystallin structure as well as segregation:

One to two grams of ammonium persulfate in 10 cc. of water. This is probably the best reagent for developing this phase of the structure in iron and steel.[1]

3. To show up the distribution of phosphorus:

Various reagents containing copper chloride are used. The copper coats those portions which are low in phosphorus and leaves the high phosphorus areas bright. It has recently been shown that nickel and other alloys give similar effects, also that oxide of iron acts in the same way. The accompanying list shows the various solutions which have been recommended:

Heyn.—Copper--ammonium chloride	10 g.
Water	100 cc.

A somewhat weaker solution is better, the specimen being etched two or three times in fresh solution if necessary. The liquid is gently agitated. The coating of spongy copper forming on the face of the specimen is easily removed with a swab of wet cotton. Portions high in carbon, sulfur and phosphorus will have darkened. If the copper film adheres, a 0.5-per-cent solution of ammonium persulfate will facilitate its removal.

Stead.—$CuCl_2$	10 g.	Dissolve salts in smallest possible amount of hot water and make up to 1000 cc. with absolute alcohol.
$MgCl_2$	40 g.	
HCl	10 cc.	
H_2O	20 cc.	
Alcohol to	1000 cc.	

For small specimens the reagent is applied drop by drop until structure is developed. The specimen is then washed with boiling water and then alcohol.

Another method is to wash off the deposited copper with ammonia and so increase the contrast.

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[1] Rawdon, "Macro-etching with Ammonium Persulphate," *Scientific Paper No 402*, Bureau of Standards (1920).

Le Chatelier and Lemoine.—

$CuCl_2$	10 g.
$MgCl_2$	40 g.
HCl	20 cc.
H_2O	180 cc.
Alcohol	1000 cc.

Applied like Stead's reagent. Contrast can be increased by electrolysis, using a single battery cell, keeping the current below 50 milliamperes.

Rosenhain and Haughton.—

Fe_2Cl_6	30 g.
HCl	100 cc.
$CuCl_2$	10 g.
$SnCl_2$	0.5 g.
H_2O	1000 cc.

The copper adheres firmly. Pearlite areas remain bright. Ferrite darkened by deposited copper, the purest parts darkening the fastest. Pitting can be avoided by diluting the reagent.

LeChatelier and Dupuy.—

Ethyl alcohol	100 cc.
H_2O	10 cc.
$CuCl_2$	1 g.
Picric acid	0.5 g.
HCl (concentrated)	1.3 to 2.5 cc., varying with material.

Oberhoffer.—

Ethyl Alcohol	500 cc.
H_2O	500 cc.
$SnCl_2$	0.5 g.
$CuCl_2$	1.0 g.
Fe_2Cl_6	30 g.
HCl	50 cc.

Humfrey.—Emery paper finish may be used for specimen.

Copper ammonium chloride	120 g.
HCl (concentrated)	50 cc. (±)
H_2O	1000 cc.

The addition of HCl causes the copper deposit to adhere. Etching is therefore started with the neutral solution and continued until all traces of the scratches have disappeared. Then in successive applications the acidity of this solution is gradually increased up to the maximum. Alloy steels etch better with solutions of weaker acidity. After wiping away the deposited copper and drying, the surface is lightly rubbed with fine emery paper and the relief portions brought out in strong contrast. The section may be printed with ordinary printer's ink applied to the surface by means of a roller.

Dickenson.—First etch with 10-per-cent HNO_3. Then re-etch with:

Fe_2Cl_6	40 g.
$CuCl_2$	3 g.
HCl	40 cc.
H_2O	500 cc.

References.

Heyn and Bauer, *Metallographie*, 1909, Vol. I, p. 21.
Rosenhain and Haughton, *Journal*, Iron and Steel Inst., 1914, Vol. I, p. 505.
Stead, *Journal*, Iron and Steel Inst., 1915, Vol. I, p. 173.
Stead, *Idem*, 1918, Vol. I, p. 408.
Le Chatelier and Lemoine, *Comptes Rendus*, 1915, 161, p. 373.
Le Chatelier and Dupuy, *Revue de Mettalurgie*, 15, p. 127.
Oberhoffer, *Stahl und Eisen*, 1916, 36, Vol. I, p. 798.
Charpy and Bonnerot, *Comptes Rendus*, 1914, 165, p. 536.
Humfrey, *Journal*, Iron and Steel Inst., 1919, Vol. I, p. 273.
Dickenson, *Idem*, p. 294.
Howe, "Metallography of Steel and Cast Iron," p. 601.

METHODS FOR INDICATING DISTRIBUTION OF SULFUR.

The distribution of sulfur is usually shown by the sulfur print method. A solution of 2 to 3 cc. of concentrated H_2SO_4 in 100 cc. of water is used to moisten a sheet of matt-finish photographic paper. The specimen with its surface smoothed either with a fine file or grinding wheel is pressed firmly on the paper on which a brown mark indicates the sulfur-rich areas. About 60 seconds is usually sufficient to give a good print. The paper is then washed and fixed in hyposulfite solution.

With larger sections the paper is placed on their polished surface with care so that no air pockets occur. If a very dilute solution is used and a longer "etch" several prints can be obtained. Fresh solution can be added with absorbent cotton should the paper tend to become dry.

References.

R. Baumann, *Metallurgie*, 1906, p. 416.
Stead, "Sulphur and Iron," Staffordshire Iron and Steel Institute, March, 1908.
Hatfield, "Cast Iron," p. 71, shows sulfur prints of pig iron.

METHODS USED FOR THE LOCATION OF MINUTE CRACKS BEFORE DEEP ETCHING.

Considerable differences of opinion have arisen as to the meaning of the results obtained by deep etching in transversely fissured rails, etc., because the presence of cracks in the material previous to etching had not been demonstrated. The following method, however, can be used to locate them. The sample after careful polishing is magnetized and then immersed in kerosene or a similar liquid containing very fine iron dust in suspension. The particles of iron dust collect upon the face of the specimen and orient themselves to correspond to the shape of the cracks because of discontinuity in the metal which causes a change in the density of the magnetic flux. The samples are then washed in clean kerosene to remove as much as possible of the excess iron dust which clings to the surface.[1]

According to several authorities their existence has been proven by annealing the specimens prior to etching, because a pronounced decarburized area then occurs around these cracks.

METHOD OF PHOTOGRAPHING.

The camera should be arranged so that the specimen is illuminated by vertical light. After certain kinds of etching, *e. g.*, ammonium persulfate, the surface should be immersed in water, alcohol or light oil. For large specimens the surface may be covered with oil or glycerin.

PRINTING THE SURFACE.

The surface obtained by deep etching may be printed with printer's ink applied with a roller. The printing can be done on a glossy paper in a letter press. For small samples of wrought iron deeply etched a reproduction can be made using an ordinary ink pad and applying the specimen as in block printing.

MICROSCOPIC EXAMINATION.

LOCATION OF TEST PIECES.

The location of the test piece for microscopic examination is of prime importance. In the case of a casting of steel or cast iron, the section ought to be cut perpendicular to the surface so as to show the variation of structure from the outside to the interior. In the case of forged and rolled metal both cross and longitudinal sections should be examined, their location being determined by the nature of the forging, etc. For crankshafts definite locations are given with reference to the tensile test specimens. For guns, tangential specimens are required and for microstructure these should be cut parallel to the axis, etc. No one specimen is of necessity representative. The usual method of taking a cross-section from rods and bars while showing segregation of the constituents fails to reveal the usual lamination in such material for which a longitudinal section is necessary. The location of test specimens may be determined by a preliminary macroscopic examination.

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[1] Rawdon and Epstein, *Technologic Paper No. 165*, Bureau of Standards (1920).

In defective material, the sample should be cut adjacent to the fracture or defect. When necessary the fracture can be protected during grinding and polishing by coating it with a heavy deposit of electrolytic copper, molten lead-tin solder or a mixture of litharge and glycerin. For hardened steel and other material liable to be tempered, fusible metals such as Rose's or Wood's alloys may be used.

METHOD OF POLISHING.

The method used for polishing specimens will depend primarily on the material to be examined and on the polishing equipment. In general, samples should not be over 1-in. square and their thickness should be less than the smallest dimension of the polished surface; otherwise there is a tendency to round off the edges during the process.

The softer material can be cut with a saw while harder metal may be cut with an emery disk or broken off with a hammer. A flat surface is at first obtained either by rubbing on a file held in a vise or by grinding on an emery wheel. In both cases it is necessary to avoid tearing the surface of the metal or causing it to flow. Perfectly smooth surfaces can be obtained by commercial surface-grinding machines.

Having obtained a flat surface in this way, the sample is next rubbed down on a series of emery papers, usually starting with No. 00 Commercial followed by Nos. 0 and 00 French Emery. These papers may conveniently be mounted on revolving disks. Rubbing on one paper is stopped as soon as the scratches from the last operation have been taken out. From the No. 00 French Emery the specimen may be taken to a revolving disk covered with broadcloth, preferably running in a horizontal position at such a speed that the polishing powders are not unnecessarily thrown off. For ordinary work, two such disks will be sufficient, the first armed with well-washed carborundum, 65 or a similar grade, while the second may be armed with well-washed alumina This is preferable to rouge because it is much cleaner.

To obtain a fine polish it is a mistake to try to save time by hurrying through the papers because if this is done, when the specimen is etched, innumerable fine lines will be revealed in the ferrite. In some cases the appearance of the ferrite is actually blurred because the metal distorted in the grinding and by the coarse grades of emery has not been subsequently removed. Under no conditions should buffing be tried, because this causes an actual flow of the metal and the structure is thereby obliterated.

No general rules can be laid down as to the method to be pursued, but common sense will tell what is right and what is wrong. For example, in grinding on the emery wheel a copious flow of water must be maintained, otherwise the surface of the sample will heat up and the structure of the metal will be modified thereby.

For material of small size, such as sheet and wire, numerous methods of mounting have been devised. For wire, various mounting media such as wax, a mixture of litharge and glycerin, fusible metals and the like can be used in a small brass container. For sheet metal, a pack can be built up of pieces of the sample with alternate layers of red fiber board, bakelite or other resistant material, the whole held together by two brass end pieces and two screws. The whole can then be polished down.

METHODS OF ETCHING.

The sample ought to be examined as polished in order to show up the non-metallic inclusions as well as cracks and other defects. In order to show up the structure of the metallic matrix various etching reagents have been used depending on the material being examined. The accompanying list gives the best of these reagents. For general work a 4-per-cent solution of picric acid in ethyl alcohol is recommended. This darkens the pearlite in steel and leaves the ferrite or cementite bright as the case may be. Long etching with picric acid in alcohol will develop the grain structure in very low carbon steel and in wrought iron. This may be done more rapidly with a 2 to 4-per-cent solution of nitric acid in ethyl alcohol (95-per-cent). For showing up pearlite alone, picric acid in absolute alcohol is best.

To distinguish between ferrite and cementite in high-carbon steels, the usual method is to boil in the sodium picrate solution, which darkens the cementite.

For hardened and tempered steel, picric acid may be used, but after etching, washing under the tap, and flooding with alcohol, the specimen should be dried by an air blast or if this is not available by shaking it in air. If the usual method of mopping on a soft towel be tried, the etching film will be spoiled.

For the study of hardened and tempered steels under high magnifications other reagents have been devised such as those of Kourbatoff.

For distinguishing between cementite and phosphide of iron in cast iron, either heat tinting or boiling with sodium picrate may be used, as recommended by Matweiff. This attacks the iron phosphide but leaves the cementite unattacked.

For revealing the segregation of the phosphorus in steel, various reagents have been used depending on the deposition of copper from a copper chloride solution, as given in the accompanying list of reagents.

Certain alloy steels, especially those high in the alloying elements, are very resistant to etching. For these special solutions have been devised such as ferric chloride for high-nickel material, caustic soda solution of hydrogen peroxide, etc., for high-speed steels.

In many cases after etching, the ferrite or cementite may be found to be more or less stained or colored. This can often be remedied by a light repolish on a chamois-skin pad. While this brightens up the ferrite or cementite, as the case may be, it markedly alters the appearance of the pearlite, giving it an abnormal structure, and therefore when this method is used, photographs should be so marked. The accompanying lists of reagents are commonly used.

References.

Sauveur, "Metallurgy and Heat Treatment of Iron and Steel," 1920, pp. 42 and 62.

Tiemann, "Iron and Steel," 1919, p. 286.

Hoyt, *Metallography*, Vol. I, p. 63 (1920).

Wawrziniok, "Handbuch des Materialprüfungswesens," p. 497.

Czochralski, *Stahl und Eisen*, II, p. 1073, p. 1129 (1915). List of reagents, p. 1132.

Goerens, *Metallography*, p. 134.

Kerns, Foundry Data Sheets, June 1 and 15, 1920. Etching Solutions for Iron and Steel.

Kourbatoff, *Revue de Metallurgie*, 2, p. 169 (1905). Contribution a l'Etude Metallographique des Aciers Trempes.

Kourbatoff, *Revue de Metallurgie*, 3, p. 648 (1906).

Pamphlet No. 403, U. S. N. Bureau of Ordnance, October, 1916.

REAGENTS FOR ETCHING.

(*a*) Solution for Normal Iron and Steel.

	(*a*)	(*b*)
Picric acid (*Igevsky*).—	4 g. picric acid.	5 g. picric acid.
	95 cc. ethyl alcohol,absolute.	100 cc. ethyl alcohol (95-per-cent).

Nitric acid.— 5 cc. HNO$_3$ (concentrated).
95 cc. ethyl alcohol (95-per-cent).

Iodine.—1.25 g. I.
1.25 g. KI.
1.25 cc. H$_2$O.
to 100 cc. alcohol.

Hydrochloric acid (*Martens and Heyn, 1904*) (*hardened steel especially*).—
1 cc. HCl (sp. gr. 1.19).
100 cc. alcohol.

May dilute to 500 cc. water: 1 of HCl, using very weak current.

(*b*) SOLUTIONS FOR HARDENED STEEL.

Kourbatoff's Solutions.—

1. A. Solution.— 4 cc. HNO_3.
96 cc. amyl alcohol.
5 min., troosto sorbite brown, austenite yellow, martensite white.

2. C. Solution —1 part amyl alcohol
1 " ethyl " (1).
1 " methyl "
1 " of 4-per-cent HNO_3 in acetic anhydride (2).
Colors troostite and troosto-sorbite. Mix 1 and 2 just before using.

3. 2 parts methyl alcohol.
2 " ethyl "
2 " amyl "
1 " butyl "
3 " of 4 per cent HNO_3 in acetic anhydride.
For troostite.

4. 4-per-cent HNO_3 in methyl alcohol to which 1/10 its volume of 4-per-cent picric acid in ethyl alcohol is added.
Colors austenite, martensite and troosite differently.

5. D. Solution.—1 volume of 4-per cent HNO_3 in ethyl alcohol.
3 volumes saturated solution of nitrophenol in ethyl alcohol.
10 min. colors troosto-sorbite and martensite needles.

6. B. Solution.—1 volume of saturated solution of ortho-nitrophenol in alcohol.
2 volumes of 20-per cent HCl in amyl alcohol.
Differentiates the various constituents.

7. 1 volume of HNO_3 in alcohol
3 volumes of saturated solution of nitraniline.
Colors troostite, troosto-sorbite and martensite needles.

Benedicks.—5-per-cent meta-nitrobenzol sulfonic acid in alcohol 0.15″ darkens martensite more than austenite.

(*c*) SOLUTIONS FOR CARBIDES, ETC.

Kourbatoff.— 2 g. picric acid.
98 cc. of 25-per-cent NaOH in water.
Used boiling 5 to 10 min. Cementite colored. Also Fe_nW, Fe_2W_2C, etc., in tungsten steels while WC is unattacked. Ferrite unattacked.

Matweieff.—Neutral sodium picrate washed several times with distilled water.
Solution used boiling. 20 min. Iron phosphide attacked, cementite unattacked.

Yatsevitch.—10 cc. H_2O_2 (commercial).
20 cc. of 10-per-cent NaOH in water.
10–12 min. For high speed steel. Use fresh. Tungsten carbide darkened.

Hilpert and Colver-Glauert.—3 to 4 per cent of a saturate solution (aqueous) of SO_3 in alcohol or water.
7 sec. to 1 min. For non-pearlitic steels and pig iron.

Murakami.—10 g. potassium ferricyanide.
10 g. potassium hydroxide.
100 cc. water.

Use hot. Distinguishes between carbide and tungstide in high speed and in tungsten steels.

(*d*) SOLUTIONS FOR ALLOY STEELS.

Ferric chloride.—Fe_2Cl_6, 5 g.
HCl 50 cc.
Water 100 cc.

Used for austenitic nickel steels.

Electrolytic.—Aqueous solution of 0.5-per-cent NaOH with very weak current. On 110 volt circuit use two 4 c. p. lamps in series, connected with two wire terminal (platinum wire preferable). Flood specimen's surface with solution. Make contact with one wire at side and dip the other with the solution, moving it around to obtain uniform etch. Used for stellite, high chrome, etc.

METHODS FOR IDENTIFICATION OF NON-METALLIC INCLUSIONS.

Stead.—Dilute H_2SO_4 (1 : 3 H_2O). Bubbles from sulfides, none from silicates.

Law.—Uses an acid solution of lead or cadmium salt in gelatin. The sulfides form deep brown or yellow stain of cadmium or lead sulfide.

Electrical etching solution: Distilled water with 0.002-per-cent ammonium chloride or caustic potash solution used boiling. After a few minutes wash and dry with alcohol.

MnS unaltered.
Oxide completely removed.

Matweieff.—Action of hydrogen at high temperatures.
- Oxides (MnO FeO)—reduced.
- Silicates—unaffected.
- Sulfides—unaffected.

Action of vapor of water at high temperatures.
- Oxides—attacked.
- Silicates—unattacked.
- Sulfides—unattacked.

Action of organic acids.
- Oxides—unattacked.
- Silicates—unattacked.
- Sulfides—attacked.

Distinction between FeO and MnO.
- Reduction by hydrogen—repolished.
- Dilute alcohol solution of $FeCl_3$.
  - If colored deep—MnO with some FeO.
    MnO alone is not reduced.
  - If colored feebly—FeO.

Distinction between FeS and MnS.
- FeS—colored by solution of tartaric acid.
- MnS—very feebly colored.

Rohl.—Sulfides 1-per-cent acetic, citric, oxalic or picric acid in water.

FeS always more readily blackened in one minute. MnS blackened slightly after 45 seconds.

Picric acid gives most uniform results.

1-per-cent acetic or picric acid in ethyl alcohol can be used.

Etching by picric acid (4 g. acid + 100 cc. amyl alcohol then by dilute HNO_3) (4 cc. + 100 cc. amyl alcohol) then by concentrated hot NaOH solution. Dark brown color due to sulfides.

Sodium acetate 2 per cent aqueous—1 minute.

FeS—brownish tint.

MnS—very light.

Reduction Tests.

(1) $HgCl_2$ solution.

Sulfides covered with Hg especially FeS.

Repolishing (softly) FeS—corroded, MnS—not corroded.

(2) $AgNO_3$ solution. (3-per-cent solution boiling.)

FeS—uniform violet blue.

MnS—dove gray slightly darkened.

Repolishing:

FeS—reddish violet.

MnS—blue gray.

Rohl's Method of distinction:

(1) Organic acid 1 per cent in ethyl alcohol with 5 minutes etching.

FeS darkens more than MnS.

(2) A short preliminary etching. With 1 per cent picric acid in ethyl alcohol followed by tempering to dark yellow.

FeS—a beautiful dark blue to reddish violet.

MnS—dull gray to bright white.

SULFIDES.

McCance.—

Whiteley's Reagent	5 g. gelatin + 20 cc. H_2O, soak for one hour and add 15 cc. glycerin. Heat till clear, add 0.05 g. tartar emetic in 1 cc. H_2O, filter and add 1 cc. dilute H_2SO_4. Apply warm.
	Yellow ring forms around sulfides.
McCance's Reagent	Replace tartar emetic by 0.1 g. $AgNO_3$.
	Black stain indicates sulfide.

FOR SILICATES AND OXIDES.

McCance.—

A.	HF	2 cc.	For steels, about 3 sec. darkens sulfides, and silicates. Oxides unattacked.
	absolute alcohol	98 cc.	
B.	HF	8 cc.	
	H_2O	42 cc.	
	Alcohol	50 cc.	

Comstock.—Uses boiling alkaline picrate of soda. MnS blackened and roughened. Silicates and oxides unaffected.

REFERENCES.

Stead, *Iron and Steel*, IX, p. 105.
Law, *Journal*, Iron and Steel Inst., II, 94 (1907).
Matweieff, *Revue de Metallurgie*, VII, p. 447.
Rohl, *Journal*, Iron and Steel Inst. Carnegie Memoir, IV, p. 28 (1912).
McCance, *Journal*, Iron and Steel Inst., 1-239 (1918).
Comstock, *Transactions*, A. I. M. E., LVI, 553 (1916).

MEANS FOR THE IDENTIFICATION OF NON-METALLIC INCLUSIONS.

As Polished

FeS.	Brownish yellow.
MnS.	Slate blue, smooth.
FeS_xMnS_y	Slate blue to brown, may show duplex structure
FeO.	Slate blue, rough, a little darker than MnS.
MnO.	Similar.
Mn—Silicate.	Greenish tinge, smooth and greasy.
Fe—Silicate.	Black and greasy.
Al_2O_3.	Tiny hard rounded grains, never elongated by rolling, etc.
Sand Grains.	Angular form, convex side, greasy appearance standing in high relief.
Titanium nitride or cyanonitride.	Pink or yellow cubic crystals.

	SULFIDES.	OXIDES.	SILICATES.
H_2SO_4 (1 : 3 H_2O)	Gas bubbles.	No action.	No action.
Pb or Cd. salt in gelatin.	Brown or yellow stain.	" "	" "
McCance's Reagent, $AgNO_3$ in gelatin.	Black stain.	" "	" "
Acetic, citric, oxalic, etc.	Attacked.	" "	" "
Boiling sodium picrate.	Black and rough.	" "	" "
H or H_2O at 600° C.	No change.	Reduced or attacked.	" "
2 cc. HF in alcohol, 3 sec. etch.	Darkened.	No action.	Darkened.
Electrolysis (0.002-per-cent NaOH).	No change.	Removed.	No change.

	FeS	MnS
As polished	Brown-yellow.	Slate blue—smooth.
Tartaric acid	Colored.	Colored, less.
1-per-cent picric alcohol. 5 min	Blackened.	Less so.
Ditto. Heat tint to dark yellow	Blue-violet.	Dull gray white.

	FeO	FeO_xMnO_y	MnO
H at 600°	Reduced.	Reduced.	Unreduced.
Electrolysis (0.002-per-cent NaOH)	"	"	"
Alcohol Fe_2Cl_6 solution after electrolysing and repolishing	Feeble color.	Deep color.	Not reduced.

TENTATIVE DEFINITIONS OF TERMS RELATING TO METALLOGRAPHY.[1]

Serial Designation: E 2 - 21 T.

These definitions are issued under the fixed designation E - 2; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

ISSUED, 1921.

Achromatic.—See Lens.

Alloy.—A product possessing metallic characteristics resulting from two or more metals, or a metal and a non-metallic substance. It is essential that the components be miscible, at least to some extent when in the molten state and that they shall not entirely separate from each other into distinct layers upon solidifying.

Alpha Brass.— A copper-zinc alloy with a copper content greater than approximately 64 per cent. It is composed of but one type of crystals, all of which are of the same composition.

Apochromatic.—See Lens.

Etching Reagent.—A solution, usually either acid or alkaline, generally of very low concentration, used to reveal the structure of a metal by the difference in the rate of solution of different parts or of different grains.

Equi-axed.—This term is applied to the grains of a metal or alloy after solidification and to grains of metals or alloys which have been strained and allowed by a process of suitable annealing to assume a condition approaching crystalline equilibrium.

Grain.—A synonym for the crystals of metals and of one-constituent alloys. Although a crystal may show subdivision by "twinning," etc., it is regarded as the grain rather than the smaller subdivisions. In the case of alloys of more than one constituent, the crystal which, by its transformation gave rise to these constituents, is taken as the grain when its limits are still discernible, if not, the individual constituents are considered as grains.

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[1] Criticism of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr. G. F. Comstock, Secretary of Committee E-4 on Metallography, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.

These definitions of terms, when adopted as standard, will become a part of the present Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys (Serial Designation: E 2 - 20), A.S.T.M. Standards Adopted in 1920.

REFERENCES.

Stead, *Iron and Steel*, IX, p. 105.
Law, *Journal*, Iron and Steel Inst., II, 94 (1907).
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MnO.	Similar.
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Al_2O_3.	Tiny hard rounded grains, never elongated by rolling, etc.
Sand Grains.	Angular form, convex side, greasy appearance standing in high relief.

Titanium nitride or cyanonitride. Pink or yellow cubic crystals.

	SULFIDES.	OXIDES.	SILICATES.
H_2SO_4 (1 : 3 H_2O)	Gas bubbles.	No action.	No action.
Pb or Cd. salt in gelatin.	Brown or yellow stain.	" "	" "
McCance's Reagent, $AgNO_3$ in gelatin.	Black stain.	" "	" "
Acetic, citric, oxalic, etc.	Attacked.	" "	" "
Boiling sodium picrate.	Black and rough.	" "	" "
H or H_2O at 600° C.	No change.	Reduced or attacked.	" "
2 cc. HF in alcohol, 3 sec. etch.	Darkened.	No action.	Darkened.
Electrolysis (0.002-per-cent NaOH).	No change.	Removed.	No change.

	FeS	MnS
As polished	Brown-yellow.	Slate blue—smooth.
Tartaric acid	Colored.	Colored, less.
1-per-cent picric alcohol. 5 min	Blackened.	Less so.
Ditto. Heat tint to dark yellow	Blue-violet.	Dull gray white.

	FeO	FeOxMnOy	MnO
H at 600°	Reduced.	Reduced.	Unreduced.
Electrolysis (0.002-per-cent NaOH)	"	"	"
Alcohol Fe_2Cl_6 solution after electrolysing and repolishing	Feeble color.	Deep color.	Not reduced.

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Grain.—A synonym for the crystals of metals and of one-constituent alloys. Although a crystal may show subdivision by "twinning," etc., it is regarded as the grain rather than the smaller subdivisions. In the case of alloys of more than one constituent, the crystal which, by its transformation gave rise to these constituents, is taken as the grain when its limits are still discernible, if not, the individual constituents are considered as grains.

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[1] Criticism of these Tentative Definitions are solicited and should be directed, preferably before January 1, 1922, to Mr. G. F. Comstock, Secretary of Committee E-4 on Metallography, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.

These definitions of terms, when adopted as standard, will become a part of the present Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and Alloys (Serial Designation: E 2 - 20), A.S.T.M. Standards Adopted in 1920.

Grain Size.—This is preferably expressed as the number per unit area of cross-section. The average cross-sectional area of the grain may also be given or the average dimensions. Grain size of strained material is expressed by the average number per linear unit in two directions, or by the average number per unit cross-sectional area, together with the ratio of length to breadth (L/B).

Illuminator.—A totally reflecting prism or a thin plate of glass 45 deg. to the course of the ray of light placed within the tube of the microscope just above the objective lens to reflect the light which is admitted through an aperature in the tube upon the metal specimen. The prism obscures one side of the lens but illuminates the specimen much more intensely than does the glass reflector.

Intercept Method for Grain Count.—The number of grains per unit cross-sectional area is determined by counting the number of grains along a line of known length on two axes at right angles to each other.

Lens.—As used here this term refers either to the combination of simple lenses which makes up the *objective*, by means of which a real image of the object is produced within the tube of the microscope, or the *ocular*, or eye piece, which enlarges the real image formed by the objective in the focal plane of the ocular.

The lens system includes both objective and ocular.

Achromatic objectives are constructed by a suitable combination of optical glasses of different indices of refraction so that correction for two colors, red and violet, is made, thus reducing chromatic aberration considerably. In *apochromatic lenses* this correction is carried very much further so that three colors are brought to the same focus.

In the design of objectives for ordinary microscopic work (biological) allowance is made for the glass cover which is placed over the object. In metallurgical microscopes no cover glass is used, hence an allowance must be made in the design of the lens.

Macrograph.—A photographic reproduction of the appearance of any object which has been magnified not more than 10 times—shortened form of *photomacrograph.*

Magnification.—This is expressed in terms of "diameters" and indicates the ratio of the length of a dimension of the image to the real length of corresponding dimension of the object. It is indicated thus: × 100, or 100 diameters.

Metal.—Any of the metallic elements, either of very high purity or of ordinary commercial grades.

Micrograph.—A photographic reproduction of an object magnified more than 10 times—shortened form of *photomicrograph.*

Muntz Metal.—A term often loosely applied to a brass, *i. e.*, a copper-zinc alloy, that can be mechanically worked while hot. Originally applied to brass of the composition: copper 60 per cent, zinc 40 per cent; such brasses consist of a mixture of two constituents termed α and β. The name is that of the metallurgist who first prepared it.

Planimetric Method for Grain Count.—A method depending upon counting the number of grains and fractions of grains within a definite area.

TENTATIVE REVISIONS
OF
A.S.T.M. STANDARDS

Tentative Revisions of A.S.T.M. Standards are printed for one or more years with a view of eliciting criticisms, of which the committee concerned will take due cognizance before recommending final action.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Revisions to the officer of the appropriate committee, whose name and address appear in the footnote in connection with each revision.

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS.

STANDARD SPECIFICATIONS AND TESTS FOR PORTLAND CEMENT.

(Serial Designation: C 9 - 21).[1]

A revision in the form of a separate tentative specification entitled "Specifications and Tests for Compressive Strength of Portland Cement Mortars (C 9 - 16 T)"[2] is intended to become a part of the present standard specifications.

STANDARD SPECIFICATIONS FOR PURITY OF RAW TUNG OIL.

(Serial Designation: D 12 - 16).[3]

1. *Section 1.*—In the table of properties, omit the words "Browne's Method" after "Heating Test;" and omit the line "Iodine Jelly Test, minutes . . . . . . 4."

2. Replace the description of the Heating Test (Browne's Method) by the following:

Heating Test:

Preparation of Sample for Heating Test.—Five grams of hydrated lime, $Ca(OH)_2$, (at least 72 per cent CaO) shall be added to 100 cc. of tung oil. The mass shall be stirred at intervals for fifteen minutes and then filtered through a quantitative ribbed filter paper. The funnel should be covered with a watch glass. The oil so obtained shall then be submitted to the heat test.

Test tubes containing the oil should be 15 cm. by 16 mm., with a mark near the bottom to indicate 5 cc., and closed by a cork so perforated that a glass rod 3 mm. in diameter can move freely.

Fill an 800-cc. glass beaker (height, 15 cm.; diameter, 10 cm.), with cottonseed oil or soya bean oil to a height of 7.5 cm. Place a thermometer so as to be 1.5 cm. from the bottom of the bath. (See Fig. 1.)

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[1] 1921 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. P. H. Bates, Secretary of Committee C-1 on Cement, Bureau of Standards, Washington, D. C.

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I (1920).

[3] 1921 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. R. L. Hallett, Chairman of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

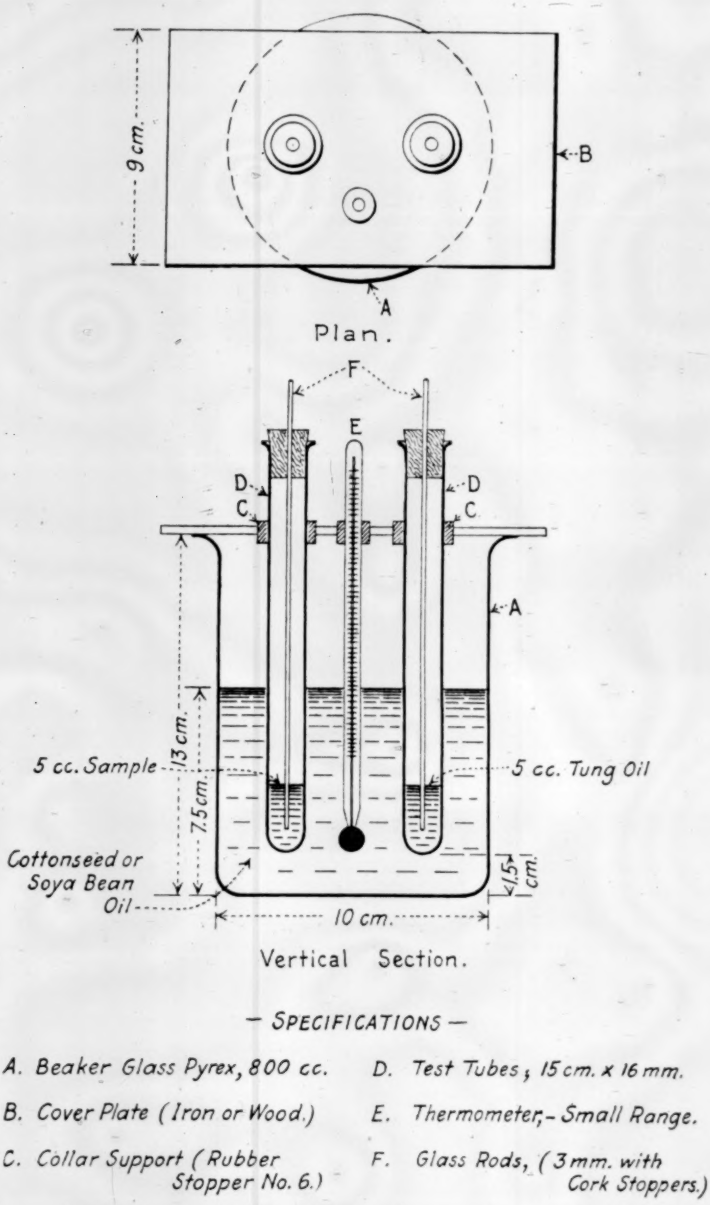
9 cm.
B
A
Plan.
F
E
D
D
C
C
A
13 cm.
7.5 cm.
5 cc. Sample
5 cc. Tung Oil
Cottonseed or Soya Bean Oil
1.5 cm.
10 cm.
Vertical Section.
— SPECIFICATIONS —
A. Beaker Glass Pyrex, 800 cc.
B. Cover Plate (Iron or Wood.)
C. Collar Support (Rubber Stopper No. 6.)
D. Test Tubes; 15 cm. x 16 mm.
E. Thermometer, - Small Range.
F. Glass Rods, (3 mm. with Cork Stoppers.)

FIG. 1.—Tung Oil Heat Test Apparatus (Revised 1920).

NOTE: Collars *C* may be omitted and tubes supported in present place by aid of wire gauze placed in bottom of oil bath and resting on bottom of beaker.

Use a nitrogen-filled, chemical thermometer; engraved stem; total length 4 to 4½ in., graduated from 210 to 310° C. in 2° intervals; the length between 210 and 310° C. not less than 2½ in. Thermometer glass shall be well annealed.

When the bath temperature is 293° C. (560° F.) and very slowly rising at this point, place the tube containing 5 cc. of the oil to be tested and the tube containing 5 cc. of the control sample, so that the bottom of each tube is level with the lowest part of the bulb of the thermometer. If desired, the collars *C* may be omitted and the tubes allowed to rest upon a piece of wire gauze placed in the bottom of the oil bath so that the tubes will be 1.5 cm. from the bottom of the bath. Note the time. Remove the source of heat for about 45 seconds and then reapply. Before 2 minutes have elapsed the temperature of the bath will have fallen to 282° C. (540° F.), at which point it should be kept as steady as possible. When the samples have been in the bath 9 minutes, raise the glass rods at intervals of ¼ minute. Note the time when each sample becomes firmly set. At this period the oil will be so stiff that the entire tube may be lifted by aid of the rod if the collar *C* is omitted from the apparatus. As setting or jellying takes place within a few seconds of fluidity, a good end determination is afforded. Remove the specimens. Heat the bath again to 293° C., and repeat the experiment with fresh portions of the sample.

No stirrer is used in the bath. A screen around the bath enables the temperature to be more easily reached. When the bath oil has become tarry and viscid, it should be renewed; otherwise heating may be irregular.

3. Omit the description of the Iodine Jelly Test.

STANDARD METHODS OF LABORATORY SAMPLING AND ANALYSIS OF COAL.

(SERIAL DESIGNATION: D 22 - 16).[1]

A revision in the form of a separate tentative method entitled "Method of Test for Fusibility of Coal Ash (D 22 - 19 T)"[2] is intended to become a part of the present standard methods.

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[1] 1921 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. A. C. Fieldner, Chairman of Committee D-5 on Coal, Fortieth and Butler Sts., Pittsburgh, Pa.

[2] *Proceedings*, Am. Soc. Test. Mats. Vol. XX, Part I (1920).

STANDARD DEFINITIONS OF TERMS RELATING TO PAINT SPECIFICATIONS.

(SERIAL DESIGNATION: D 16 – 15).[1]

A revision in the form of additional definitions of terms entitled "Tentative Definitions of Terms Relating to Paint Specifications (D 16 – 21 T)"[2] is intended to become a part of the present standard definitions.

STANDARD DEFINITIONS AND RULES GOVERNING THE PREPARATION OF METALS AND ALLOYS.

(SERIAL DESIGNATION: E 2 – 20).[3]

A revision in the form of additional definitions of terms entitled "Tentative Definitions of Terms Relating to Metallography (E 2 – 21 T)"[4] is intended to become a part of the present standard definitions.

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[1] 1921 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. R. L. Hallett, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 129 York St., Brooklyn, N. Y.

[2] See p. 629.

[3] 1921 Book of A.S.T.M. Standards. Criticisms of this revision are solicited and should be directed to Mr. G. F. Comstock, Secretary of Committee E-1 on Metallography, Titanium Alloy Manufacturing Co., Niagara Falls, N. Y.

[4] See p. 829.

TECHNICAL PAPERS

WITH DISCUSSIONS

IMPACT TESTS ON CAST STEEL.

By F. C. Langenberg.

From time to time the writer has been called upon to make impact tests on cast steel of varied compositions and heat treatments. The results recorded herein were obtained from four investigations, which can be briefly outlined as follows:

1. Investigation to determine the effect of phosphorus upon the physical properties of cast steel, made in the converter.
2. Examination of castings having different carbon and manganese content. These castings were manufactured by a private concern, the steel being made in a 3-ton basic electric furnace.
3. Experimental heat treatment of acid open-hearth cast steel.
4. Summary of impact tests obtained on forged steel submitted for comparative purposes with the results obtained on castings.

The nomenclature, cast steel Nos. 1, 2 and 3 is used throughout this report, and refers to the Ordnance Department classification of cast steel. In the original Ordnance Department specifications the only chemical requirement imposed upon the manufacturer was that the phosphorus should not exceed 0.05 per cent and the sulfur 0.07 per cent. During the war period these specifications were revised several times, and finally resulted in the following classification:

	Elastic Limit, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation, per cent.	Contraction, per cent.
Cast Steel No. 1....	27 000	60 000	22	30
" " No. 2....	31 500	70 000	18	25
" " No. 3....	36 000	80 000	15	20

I. Investigation to Determine the Effect of Phosphorus Upon the Physical Properties of Cast Steel.

Experimental.

For convenience in discussion, the experiments presented under this heading are divided into two groups.

The first experiment consisted in making two pintle-bearing castings and four test coupons, two of the coupons and one of the castings having a phosphorus content of 0.043 per cent, and the other two coupons and casting having a phosphorus content of 0.104 per cent.

In the casting of these coupons and castings the following procedure was adopted:

A regular No. 3 converter heat was selected, the ladle analysis of which showed the following composition: Carbon, 0.42 per cent; Manganese, 0.86 per cent; Silicon, 0.197 per cent; Sulfur, 0.065 per cent; Phosphorus, 0.039 per cent.

A small ladle was preheated and placed on the scales, and enough 20-per-cent ferrophosphorus added to this ladle to bring 800 lb. of metal from 0.04 per cent phosphorus to 0.10 per cent phosphorus.

Immediately after the heat was down (cast-steel heat 5775) and properly recarburized, 800 lb. of metal was added to the small ladle. One casting and two coupons were then poured from the regular composition, and one casting and two coupons from the small ladle. The phosphorus, as determined from a sample taken from one of the coupons of the regular composition, was 0.043 per cent, whereas that determined from a sample taken from one of the high phosphorus coupons was 0.104 per cent.

Experiment No. 2 consisted in making four different phosphorus contents from one regular No. 3 heat of converter steel. The procedure adopted was as follows:

A small ladle was thoroughly preheated as in experiment No. 1 and ferrophosphorus additions made to this ladle. As soon as the heat was down and properly recarburized, 1200 lb. of metal were added to the small ladle. Two pintle-bearing castings and two coupons were poured from the regular composition from the large ladle. Two castings and two coupons were then poured from the higher phosphorus metal from the small ladle, thus emptying the small ladle.

Ferrophosphorus additions were again made to the small ladle and 1200 lb. of metal added. The remaining metal in the large ladle was then "doped" with ferrophosphorus, so as to bring its phosphorus content from the original estimated 0.04 per cent to 0.08 per cent. Two pintle-bearing castings and two coupons were then poured from both the large and the small ladle, thus consuming the entire heat.

The eight castings and eight coupons were then heat treated by annealing them at 950° C. for two hours, chilling in air and then drawing for four hours at 500° C.

Results of Experiment No. 1.

Two test coupons marked 5775-1 and 5775-2, one pintle-bearing marked 5775, two test coupons marked 5775-3*X* and 5775-4*X*, and one pintle bearing marked 5775*X* were annealed at 950° C. for two hours and then air chilled. Subsequent to the air-chilling operation, they were drawn four hours at 500° C. The letter "*X*" was used to designate all castings and coupons having a high phosphorus content. A number of determinations were made on samples taken from coupons and cut tests, and it is believed that the following composition fairly represents that which was actually present.

MATERIAL.	CARBON, PER CENT.	MANGANESE, PER CENT.	SILICON, PER CENT.	SULFUR, PER CENT.	PHOSPHORUS, PER CENT.
Coupon 5775-1..	0.42	0.86	0.197	0.065	0.043
Coupon 5775-2..					
Casting 5775...					
Coupon 5775-3*X*	0.42	0.86	0.197	0.065	0.104
Coupon 5775-4*X*					
Casting 5775*X*..					

After the annealing operation outlined above had been completed, all of the coupons and one-half of each casting were cut up for test. Charpy tests only were taken, the results of which are tabulated below.

MATERIAL.	MEAN OF 4 TESTS, FT.-LB.
LOW PHOSPHORUS MATERIAL.	
Coupon 5775-1	6.28
Coupon 5775-2	6.90
Casting 5775	6.69
Average	6.69
HIGH PHOSPHORUS MATERIAL.	
Coupon 5775-3*X*	2.87
Coupon 5775-4*X*	2.48
Casting 5775*X*	3.95
Average	3.10

An inspection of the general averages obtained above, incorporating tests from both coupons and castings, will show that considerably higher shock strength was obtained on the low phosphorus material. An increase in the phosphorus content from 0.043 per cent to 0.104 per cent decreased the shock strength by some 53 per cent. The two remaining halves of the pintle-bearing castings were then retreated by heating to 900° C., quenching in water, followed by drawing at 600° C., a treatment used previously with considerable success on the production of this casting for which particularly high properties are demanded.

Charpy tests were then made with the following results:

Material.	Mean of 4 Tests, ft.-lb.
Casting 5775	7.76
Casting 5775*X*	3.41

From these results it is also evident that an increase in phosphorus from 0.043 per cent to 0.104 per cent has reduced the shock strength by over 50 per cent.

Results of Experiment No. 2.

As previously stated, eight castings and eight coupons were made in the second experiment. Chemical samples taken from the coupons gave the following results:

Coupon.	Carbon, per cent.	Manganese, per cent.	Silicon, per cent.	Sulfur, per cent.	Phosphorus, per cent.
5807*A*	0.42	0.65	0.282	0.069	0.043
5807*B*	0.40	0.63	0.300	0.069	0.058
5807*C*	0.42	0.60	0.273	0.066	0.068
5807*D*	0.41	0.61	0.273	0.065	0.075

The results of the tensile tests, together with the Charpy tests, the latter in each case being the average of four separate bars, are recorded below:

Marks on Specimen.	Yield, Point, lb. per sq. in.	Tensile, Strength, lb. per sq. in.	Elongation, per cent.	Contraction, per cent.	Charpy Test, ft.-lb.	Brinell Hardness.
5807*A*	51 000	89 000	21.5	24.0	5.43	163
5807*A*	52 000	87 500	15.0	16.9	5.50	149
5807*B*	51 500	87 500	17.0	20.5	4.42	192
5807*B*	50 500	86 000	17.0	20.5	4.88	175
5807*C*	51 500	88 000	19.0	16.9	3.25	...
5807*C*	52 000	89 500	19.5	24.0	3.88	...
5807*D*	52 500	82 500	7.5	9.5	2.40	...

Coupon discarded.

Fig. 1 was plotted from the results of these tests. It is very evident from this curve that the phosphorus content has a very decided relationship to the Charpy value. It would appear from this figure that the most decided decrease or falling off of the Charpy value occurs when the phosphorus content is increased beyond 0.06 per cent. In considering this curve it should be borne in mind that all of this material was poured from one heat, and that all conditions, excepting the phosphorus content, were maintained constant. That such was the case is further proven by the fact that very little difference can be observed in the results of the ordinary static tensile test, excepting 5807*D* which showed a decided falling off in ductility. It would appear that if experimental conditions had varied to any great extent, the ordinary static tensile test would have shown more disagreement than is recorded.

It is particularly noticeable also that the effect of slight increases in phosphorus make themselves much more apparent by their influence upon the shock strength than upon the results of the tensile strength; 5807*C*, for example, shows static tests very similar to 5807*A*. The shock test, however, is decidely inferior to that obtained on the low phosphorus material.

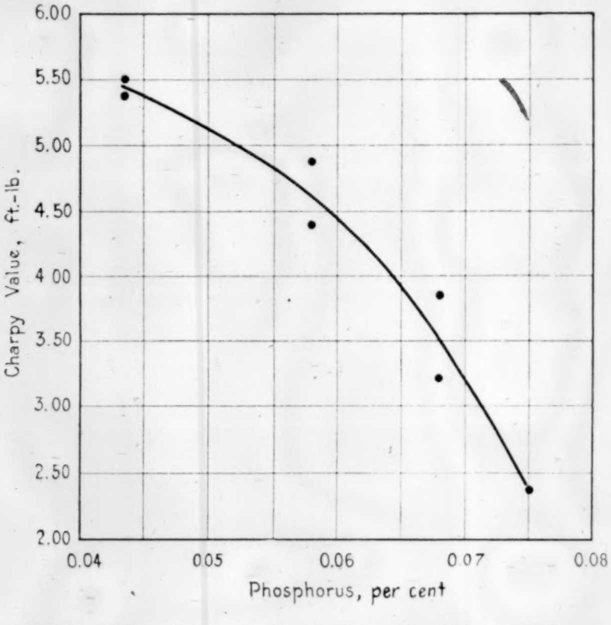

FIG. 1.—Effect of Phosphorus on Shock Strength of Steel Castings.
Each point in the curve is the average of four tests.

The eight castings, two of each composition, which have been previously referred to, were tested to destruction under a drop. Rough as this test was, it confirmed the results of the Charpy tests; both indicated that a decided decrease in dynamic resistance occurs somewhere between 0.06 and 0.07 per cent phosphorus, and the indications are that this sudden decrease in dynamic resistance occurs more nearly at 0.06 per cent than at 0.07 per cent phosphorus.

II. EXAMINATION OF CASTINGS HAVING DIFFERENT CARBON AND MANGANESE CONTENT.

Material.

Eight castings were received in the laboratory. These castings had all been air chilled at a temperature of 900° C. The pattern number, heat number, and composition of the castings were as follows:

PATTERN.	HEAT NO.	SILICON,[1] PER CENT.	SULFUR,[1] PER CENT.	PHOSPHORUS,[1] PER CENT.	CARBON,[2] PER CENT.	MANGANESE,[2] PER CENT.
42..........	239	0.56	0.032	0.042	0.44	0.93
42..........	245	0.42	0.011	0.030	0.27	1.08
27..........	292	0.28	0.014	0.043	0.298	1.31
58..........	304	0.10	0.014	0.033	0.222	1.29
81 and 79....	199	0.31	0.015	0.038	0.33	1.54
42..........	276	0.26	0.016	0.047	0.346	1.76

TABLE I.—CHARPY IMPACT AND BRINELL HARDNESS TESTS.

Heat No.	Carbon, per cent.	Manganese, per cent.	Charpy Impact Values. Foot-pounds Absorbed.			Brinell Hardness Values.				Appearance of Fracture.
			First Test.	Second Test.	Average.	First Test.	Second Test.	Third Test.	Average.	
239	0.44	0.93	9.89	10.07	10.01	197	197	197	197	Amorphous and crystallin
245	0.27	1.08	32.28	30.89	31.58	149	156	153	153	Amorphous
292	0.298	1.31	29.64	34.84	32.24	171	175	167	171	"
304	0.222	1.29	25.92	29.82	27.87	163	159	159	160	"
199	0.33	1.54	8.84	8.14	8.49	207	207	212	209	Amorphous and crystallin
276	0.346	1.76	6.28	7.22	6.75	197	197	207	200	"

Remarks.

Referring to the results of the Charpy test, it will be noted that the unusual Charpy values for castings: namely, those obtained on Heats Nos. 245, 292 and 304, occurred when the carbon did not exceed 0.30 per cent and the manganese 1.31 per cent. With a carbon content of 0.33 per cent and a manganese content of 1.54 per cent on Heat No. 199, the Charpy value was reduced to 8.49 ft.-lb., whereas Heats Nos. 245, 292 and 304 with lower carbon and manganese contents showed mean Charpy values varying from 32.24 to 27.89 ft.-lb. Heat No. 239, with a carbon content of 0.44 per cent and a manganese content of 0.93 per cent shows a Charpy value of 10.01 ft.-lb. It would therefore appear that the shock strength of cast steel No. 3 can be increased by lowering the carbon content and increasing the manganese content. It also seems evident that any increase in the carbon above 0.30 per cent or in the manganese above 1.30 per cent decreases the Charpy value.

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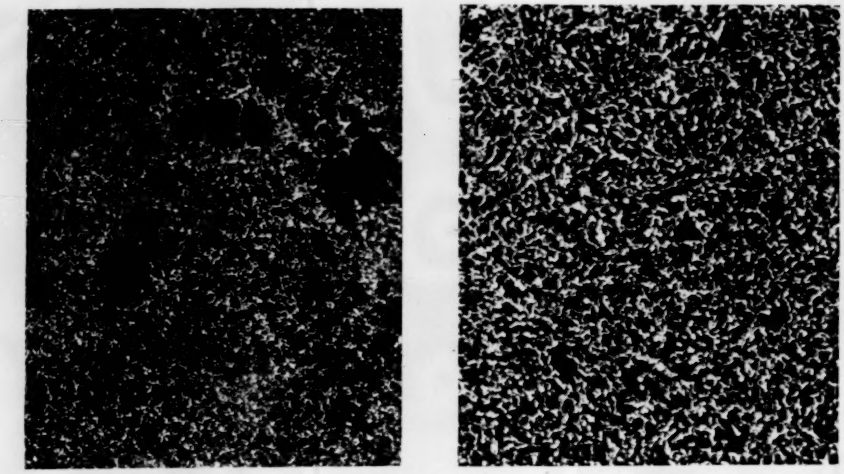
[1] Composition accompanying castings.

[2] From check analyses taken in this laboratory.



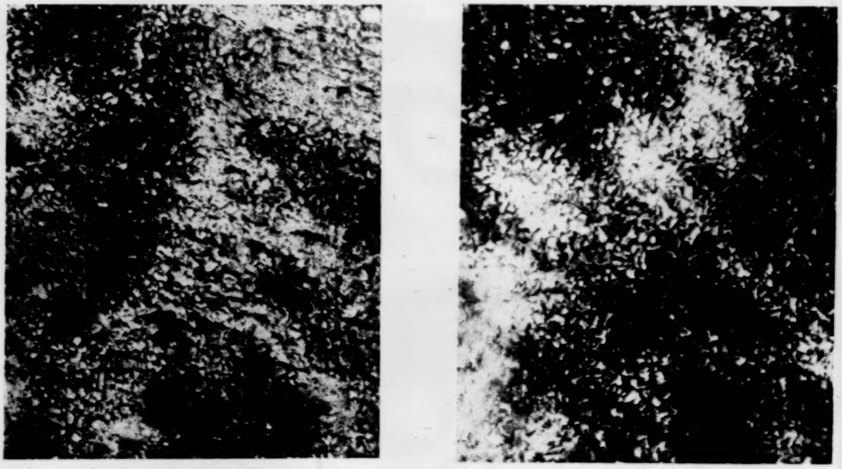
(*a*) Quenched in water from 900° C. Drawn 4 hours at 600° C.

(*b*) Annealed 2 hours at 950° C. Chilled in air. Drawn 4 hours at 500° C.

FIG. 2.—Micrographs of material in pintle bearing. Etched with nitric acid (× 50).

Composition, per cent:

	C.	Mn.	Si.	S.	P.
(*a*)	0.42	0.86	0.197	0.065	0.104
(*b*)	0.42	0.86	0.197	0.065	0.043



(*a*) Phosphorus 0.104 per cent.

(*b*) Phosphorus 0.043 per cent.

FIG. 3.—Micrographs of sections taken from pintle bearings poured from same heat of steel after being heated to 950° C., chilled in air and drawn at 500° C. Compositions identical with the exception of phosphorus. Etched with Stead's reagent (× 50). Light areas show portions rich in phosphorus.

III. EXPERIMENTAL HEAT TREATMENT OF ACID OPEN-HEARTH CAST STEEL.

Experimental.

The experimental work consisted of physical, chemical, and microscopical tests of the heat-treated metal. The material consisted of slabs $1\frac{1}{2}$ in. in thickness which were cut from a 10-in. round ingot.

Heat Treatment.

Three heat treatments were applied: namely,

Treatment A.—Heated to 900° C., soaked two hours at this temperature and water quenched, followed by drawing two hours at 650° C. and furnace cooled. (See Fig. *2a* for a microstructure similar to that of this material.)

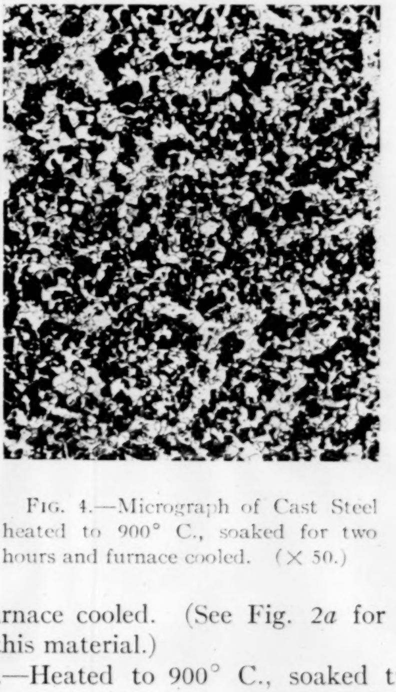


FIG. 4.—Micrograph of Cast Steel heated to 900° C., soaked for two hours and furnace cooled. (× 50.)

Treatment B.—Heated to 900° C., soaked two hours at this temperature and furnace cooled. (See Fig. 4 for the microstructure of this material.)

Treatment C.—Heated to 950° C., soaked two hours at this temperature and cooled in air, followed by drawing two hours at 500° C. and furnace cooled. (See Fig. *2b* for a microstructure similar to that of this material.)

Chemical Analysis.

The chemical analysis of the heat was as follows: Carbon, 0.30 per cent; Manganese, 0.62 per cent; Silicon, 0.181 per cent; Sulfur, 0.038 per cent; Phosphorus, 0.038.

Physical Tests.

The physical properties are recorded in Table II.

From an inspection of the mean results of the tests it is evident that water quenching has raised the elastic limit approximately 10,000 lb. per sq. in. and the tensile strength 8000 lb. per sq in. over that obtained by a simple furnace anneal. Furthermore, this has been accomplished with but little sacrifice of ductility. The shock strength, as measured by the Charpy impact strength, has been increased from 11.32 to 14.25 ft.-lb.

TABLE II.—PHYSICAL PROPERTIES OF CAST STEELS OF DIFFERENT HEAT TREATMENTS.

Marks.	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation, per cent.	Contraction of Area, per cent.	Charpy Impact Test, ft.-lb.	Brinell Hardness.
A	58 500	88 000	**15.0**	24.0	Average of 7 tests, 14.25	187
A	56 500	84 500	**11.5**	16.9		171
A	57 500	89 500	**19.5**	27.4		171
Average	57 500	87 333	**15.3**	22.8		176
B	44 000	75 000	10.5	20.5	Average of 8 tests, 11.32	156
B	50 000	82 500	25.0	37.0		153
B	45 000	80 500	19.5	24.0		159
Average	46 333	79 333	18.3	27.2		156
C	49 000	81 000	12.5	20.5	Average of 8 tests, 11.87	163
C	49 500	85 000	21.5	30.7		160
C	50 000	82 000	14.5	20.5		156
Average	49 500	82 666	16.2	23.9		159

The air-chilled specimens show an increase in both elastic limit and tensile strength of approximately 3000 lb. per sq. in. over that obtained by a simple furnace anneal. This increase is in good agreement with what has been observed in the foundry annealing practice on No. 3 steel castings. The Charpy test also shows slight improvement.

IV. CHARPY RESULTS ON FORGED STEEL.

In view of the fact that every one is not thoroughly familiar with the results obtained upon the Charpy impact machine, the following data obtained upon forged steel bars is submitted for the purpose of comparison with results on cast steel. The results given in Table III were obtained from specimens cut from bar stock approximately 1 in. in diameter, after various heat treatments. The table also shows the composition of the several bars as well as the heat treatment.

Heat treatment was as follows:

Original, as received, probably hot rolled.
V_1 Annealed just above Ac3.

TABLE III.—RESULTS OF CHARPY TESTS ON FORGED STEELS, CHARPY VALUES IN FT.-LB.

Chemical Composition, per cent.						Charpy Values in ft.-lb. for Various Heat Treatments.							
C.	Mn	S.	P	Si.	Cr.	Original.	V_1	V_2	V_3	V_4	V_5	V_6	V_7
0.14	0.45	0.035	0.018	0.131	....	45.39	28 01	38.10	47.18	47.95	49.50	48.34	52.61
0.18	0.56	0.043	0 024	0.132	....	41.51	30.72	35.69	46.24	45.00	44.62	46.87	50.51
0.32	0.51	0.027	0.009	0.128	....	22.96	15.20	10.94	18.85	19.24	19.86	22.34	26.30
0.46	0.40	0.050	0.020	0.144	....	10.70	7.99	.....	14.04	13.96	13.89	15.67	16.60
0.49	0.60	0.028	0.013	0.127	....	12.72	10.32	.....	16.06	14.51	14.35	17.53	19.24
0.57	0.65	0.028	0.012	0.167	....	8.38	7.91	.....	12.57	10.86	11.17	12.02	14.04
0.71	0.67	0.035	0.027	0.147	....	4.42	2.48	.....	.....	4.73	7.60	10.32	15.67
0.83	0.55	0.028	0.018	0.152	....	1.31	1.39	.....	.....	3.42	3.33	4.34	6.36
1.01	0.39	0.029	0.016	0.160	....	2.09	1.47	.....	.....	3.25	3.18	4.19	4.42
1.22	0.34	0.031	0.025	0.181	....	1.39	1.31	.....	.....	2.48	2.09	2.63	2.63
1.39	0.20	0.029	0.015	0.191	....	0.93	0.85	.....	.....	1.86	1.31	1.47	1.62
1.46	0.20	0.035	0.011	0.133	0.35	0.77	1.24	.....	.....	1.94	2.01	2.01	1.94

V_2 Hardened in water from just above Ac3.
V_3 Hardened in oil from just above Ac3.
V_4 Quenched in oil from just above Ac3, drawn at 375° C.
V_5 Quenched in oil from just above Ac3, drawn at 460° C.
V_6 Quenched in oil from just above Ac3, drawn at 560° C.
V_7 Quenched in oil from just above Ac3, drawn at 650° C.

DISCUSSION.

Mr. Moore.

MR. H. F. MOORE.—I should like to ask the users of steel a question, not at all in criticism of this admirable paper, but for information, and that question is: What is the significance of test results from the single-blow impact test of steel? Is that test to be regarded as a valuable control test in determining the acceptance of steel? Is it a "suitability" test of steel, and if so, for what purposes is steel with a high impact test result especially suited?

It has seemed to the speaker that the conditions under which the test is made very greatly exaggerate the severity of conditions in almost any regular service which steel can be called on to perform—surely, no such shattering overstress can come on steel in regular service.

Results of an extensive series of tests at the University of Illinois indicate that the single-blow impact test does not give any reliable indication of the resistance of steel to a large number of repetitions of working stress. The single-blow impact test seems to be in considerable favor today; just what qualities does it indicate in the steel tested?

Mr. Dix.

MR. E. H. DIX, JR. (*by letter*).—The test data presented by Mr. Langenberg are on a subject which has hitherto been only slightly attacked and one which is of considerable interest to engineers in general, that is, the shock resistance of steel castings, and the paper is within itself very complete. However, when one desires to use the results given therein in making comparison with impact tests on other materials, he at once asks what type of specimen was used, what are the details of the notch and what was the original energy of blow. Unfortunately the impact test has not reached the degree of standardization which permits of a paper being presented without giving these fundamental details.

It would also be interesting to know the degree of uniformity obtained in the Charpy tests made on the four bars in the table given on page 843, instead of just the average.

Mr. Langenberg.

MR. F. C. LANGENBERG (*Author's closure, by letter*).—In answer to Mr. Dix's inquiry: the machine used was a Charpy Pendulum Impact Machine of 30-kg. capacity. The test bar used was 2.165 in. long, 0.394 in. square, and notched in the center with a notch 0.039 in. in width. The accompanying sketch shows the details of this specimen.

In reply to Mr. Moore, I would say that the single-blow impact test on the notched bars has proved to be a useful and convenient laboratory method of comparing the qualities of certain steels in resistance to sudden stresses when in a notched condition. No claim is made that absolute results are to be obtained from this test under our present conditions or knowledge, but if the test is considered simply from its comparative results, it undoubtedly is of very considerable use. The "notched condition" is one which occurs in actual service under a number of disguises, and the test in which this condition is intentionally much exaggerated has given information from which material has been made to acquire the necessary resistance without change in design or composition. The author has done some work on the subject of repeated stresses and does not entirely agree with the conclusion drawn from the results of experiments made at the University of Illinois.

Mr. Langenberg.

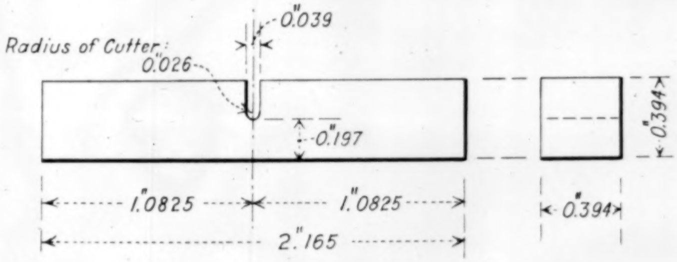


FIG. 1.—Details of Charpy Test Specimen.

COMPARATIVE TESTS OF STEEIS AT HIGH TEMPERATURES.

By R. S. MacPherran.

The following tests were made in the laboratory of the Allis-Chalmers Manufacturing Co. to determine the comparative properties of various steels at high temperatures. The work was undertaken with a view to obtaining information as to the best material for use under operating conditions of 600 to 1000° F. A large number of these tests were made on sheet metal, turbine blading and other material too thin to allow a pyrometer head to be inserted. It was therefore decided to use for all tests a heating box in which the pyrometer head was in contact with the center of the test specimen.

The heating box used was 7 in. square by 9 in. high. The hole in which the test specimen was inserted was 2 in. in diameter and was lined with a core of alundum cement wound with No. 22 gage chromel wire. This wire was wound in two coils, one over the top and one over the lower half of the alundum core. They were connected in multiple. The coils were then covered with alundum cement and the box filled with magnesia. (See Fig. 1.) The couple entered at the top of the box and ran down to such a position that the point was opposite the center of the test specimen. A spring on the outside of the box forced a porcelain rod through a hole and against the base metal couple, holding the point of same against the test specimen. The temperatures were taken by a Leeds and Northrup pyrometer, using a base metal couple. The specimens used had threaded ends and were for the most part 0.505 in. in diameter. All tests were held at constant temperature for 15 to 30 minutes before pulling. The yield points were taken by the drop of beam only and above 600° F. are very uncertain.

The heat treatment of each set of bars is indicated in its figure. The drawing temperatures are much above the usual, but as the tests were to be run as high as 1300° F. it was useless to draw the bars at lower than test temperatures.

The tungsten tool steel specimens were made from one piece of annealed $\frac{7}{8}$-in. round bar about ten feet in length. The test specimens were made over-size, then heat treated and afterward ground to definite size.

In all cases the forged test bars in any one series were made from one billet or piece of steel, this being hammered out into several one-inch rounds about 30 in. in length. These latter pieces were then

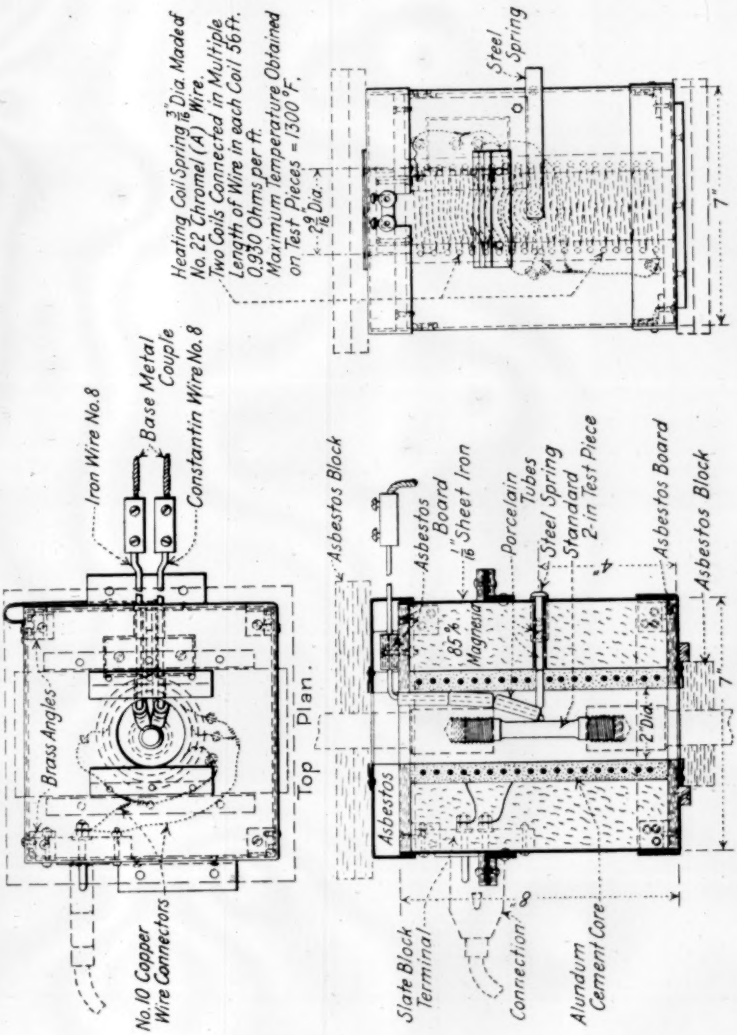

Heating Coil Spring $\frac{3}{16}$" Dia. Made of No. 22 Chromel (A) Wire.
Two Coils Connected in Multiple
Length of Wire in each Coil 56 ft.
0.930 Ohms per ft.
Maximum Temperature Obtained on Test Pieces = 1300°F.
2$\frac{9}{16}$" Dia.
Steel Spring
End View.
7"
Iron Wire No. 8
Base Metal Couple
Constantin Wire No. 8
Brass Angles
Top Plan.
No. 10 Copper Wire Connectors
Asbestos Block
Asbestos Board
$\frac{1}{16}$" Sheet Iron
Porcelain Tubes
Steel Spring
Standard 2-in Test Piece
4"
Asbestos Board
Asbestos Block
85% Magnesia
Asbestos
2" Dia.
7"
8"
Vertical Section.
Slate Block Terminal
Connection
Alundum Cement Core

Fig. 1.—Diagram of Electric Heater, showing Specimen in Position.

all heated at the same time in the same furnace and as far as possible given identical treatment. With the best of care, however, the irregularities were greater than with the rolled material tested after annealing, Fig. 5(*a*), for example, showing considerable variations in breaking loads. Fig. 5(*b*) is from rolled stock sent in by outside parties and was not treated. Figs. 3(*a*) and 3(*b*) show results of tests on carbon steel, unannealed and Figs. 3(*c*) and 4(*a*) on carbon steel, annealed. The latter are freer from irregularities due to lack of uniformity, and are therefore more representative of this class of material.

While we cannot assume definite conclusions from our limited number of tests, the following items seem to be at least probable:

1. There is no one temperature at which all steels will show a decided change in physical properties; this point will vary in steels of different compositions or treatments.

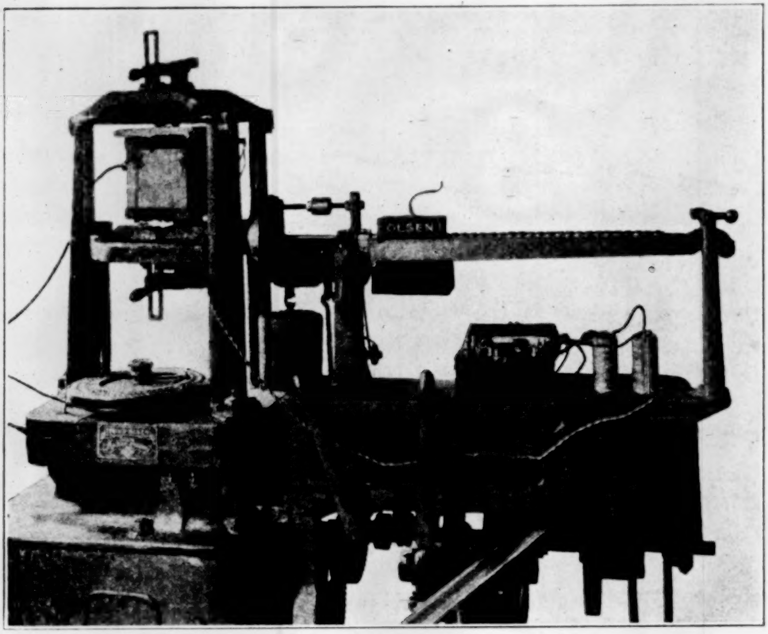


Fig. 2.—Showing Heater in Place in Testing Machine.

2. The maximum tensile strength for rolled carbon steel, annealed, and forged 3¼-per-cent nickel steel, annealed, occurs at between 600 and 650° F.

3. The maximum tensile strength usually occurs at a higher temperature than the minimum ductility.

The majority of the tensile strength curves, especially those of heat-treated steels, drop sharply as the temperatures exceed 800° F.

The effect of nickel in small amounts is slight, but in large per-

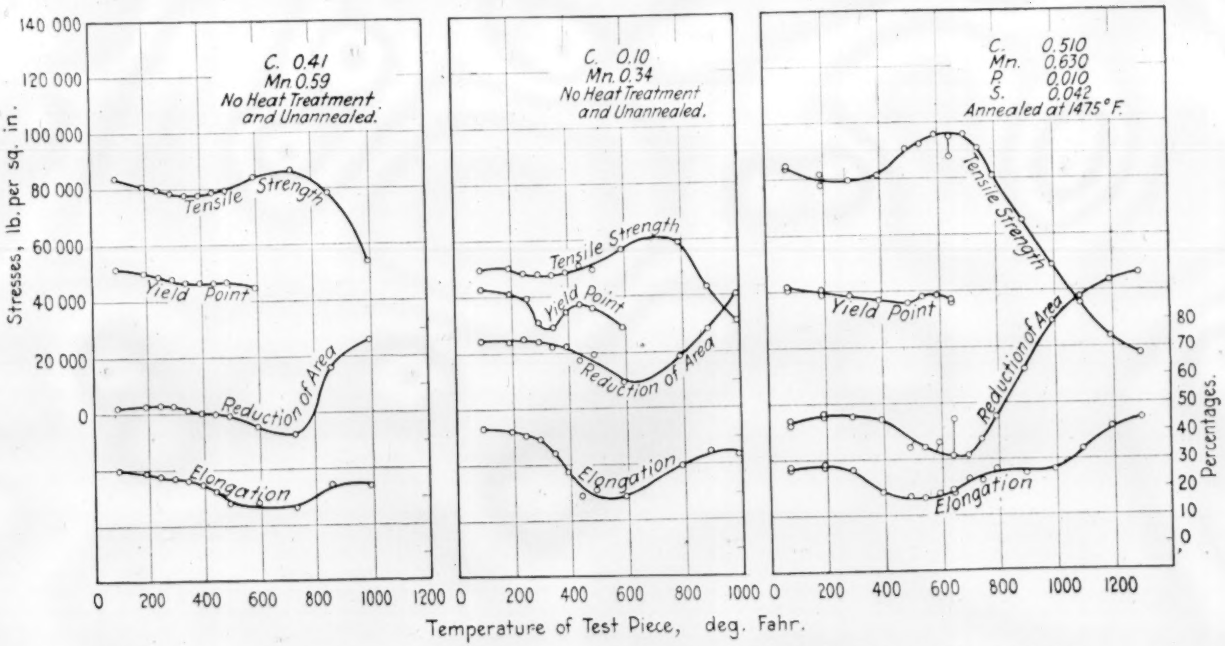
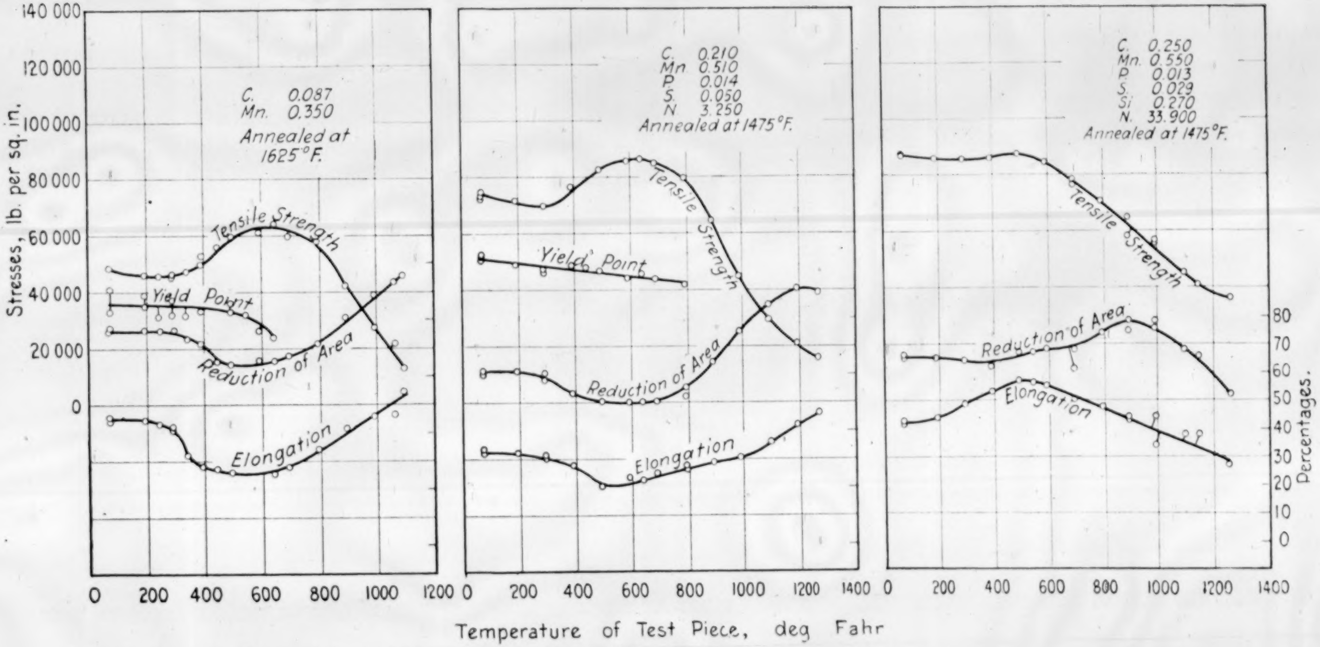
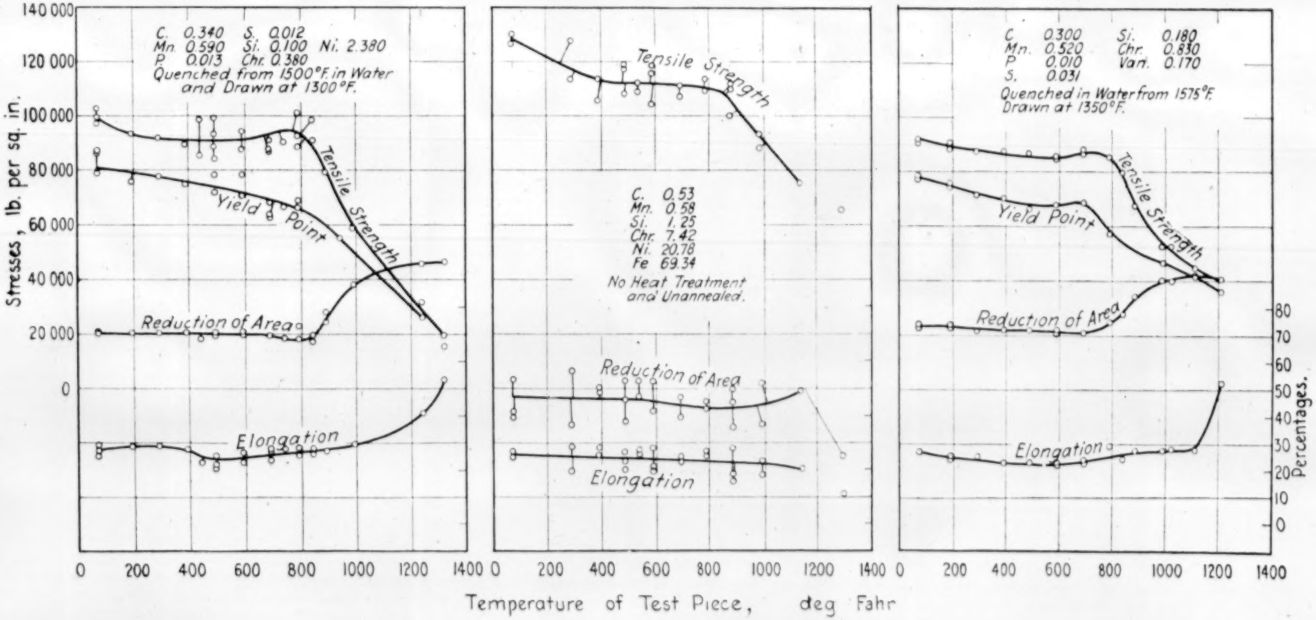


Fig. 3.—Physical Properties at High Temperatures of 1-in. Round, Rolled Open-Hearth Steel.



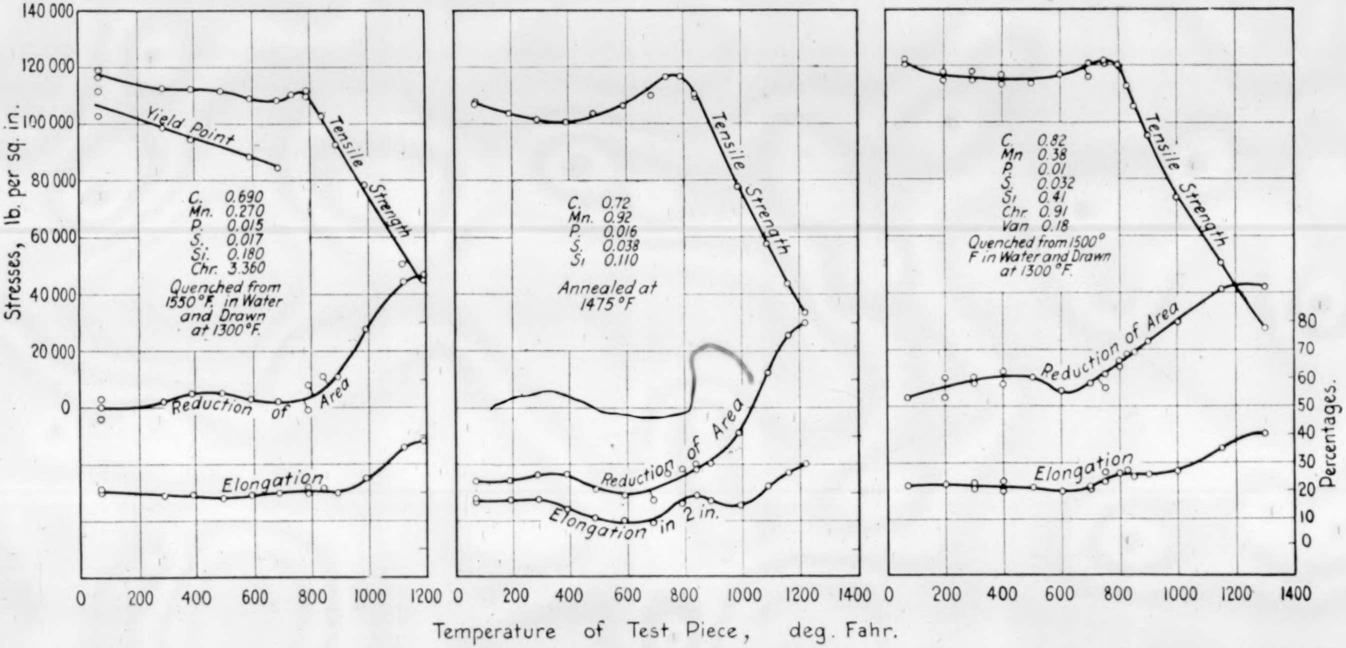
(a) $\frac{7}{8}$-in. Round, Rolled Open-Hearth Steel. (b) Forged $3\frac{1}{4}$-per-cent Nickel Steel. (c) Forged 34-per-cent Nickel Steel.

Fig. 4.—Physical Properties at High Temperatures of Carbon and Nickel Steel.



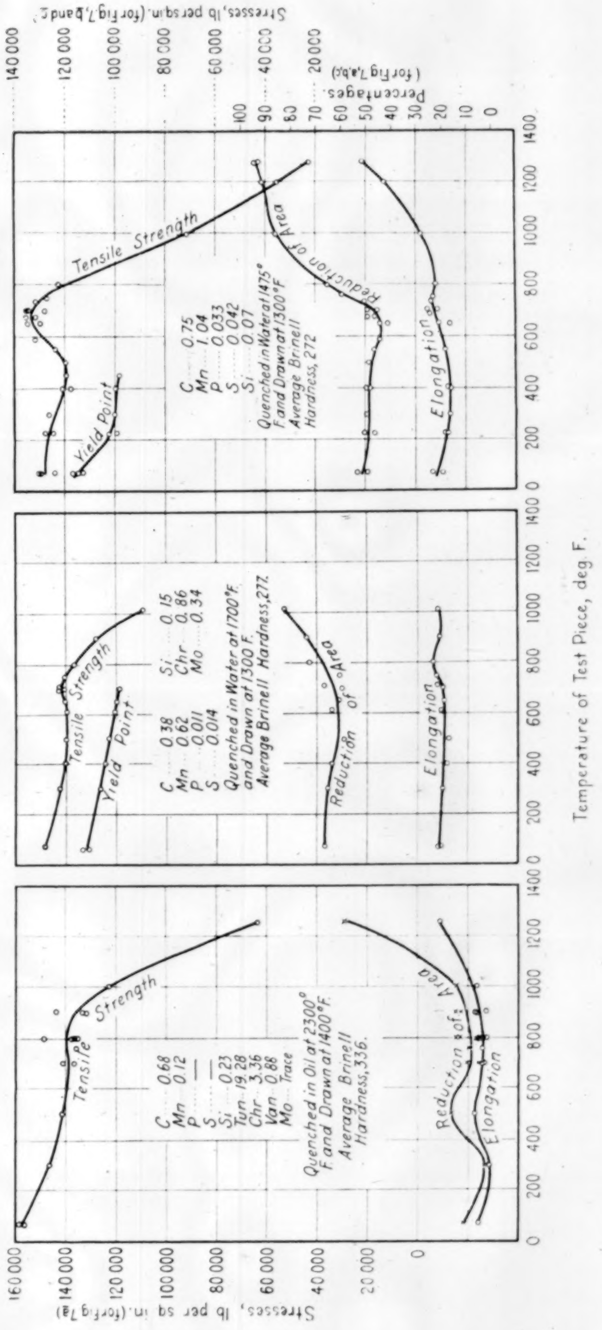
(*a*) Forged Chrome-Nickel Steel. (*b*) Rolled High-Chrome-High-Nickel Steel. (*c*) Forged Chrome-Vanadium Steel.

FIG. 5.—Physical Properties of Alloy Steels at High Temperatures.



(*a*) Forged High-Chrome Steel. (*b*) Forged High-Manganese Steel. (*c*) Forged High-Carbon-Chrome-Vanadium Steel.

FIG. 6.—Physical Properties of Alloy Steels at High Temperatures.



(a) Tungsten Tool Steel. (b) Molybdenum Steel. (c) High-Manganese High-Carbon Steel.

FIG. 7.—Physical Properties of Alloy Steels at High Temperatures.

centages it tends to lower the temperature at which tensile strength begins to decline. Steel containing nickel is also the only steel examined where the ductility materially diminishes at the higher temperatures. It may here be noted that the same property was observed in the one set we ran of forged monel metal bars.

The alloy steels containing chromium and tungsten are less affected by rise in temperature than carbon steels. The curves of the tensile loads, elongation and reduction all run out more nearly straight than in carbon steels and the maximum loads occur at higher temperatures. It is true that the carbon steels were not heat treated and it is possible that quenching and tempering would alter the shape of these curves.

The results so far obtained would indicate that the introduction of metals forming carbides tends to strengthen steels at high temperatures.

It is interesting to note that in tests for the comparative retention of physical properties in alloy steels at 1200° F. and over, Mr. Leslie Aitchison[1] finds the order of value to be:

1. Tungsten;
2. High Chromium;
3. Nickel, 3-per-cent.

It would seem with higher steam pressures and increased use of internal combustion engines that the properties of the various alloy and carbon steels at high temperatures should receive further consideration.

Acknowledgment.—In closing I wish to acknowledge the valuable assistance of Mr. J. F. Harper and Mr. E. H. Brown in carrying out this work.

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[1] Leslie Aitchison, "Valve Failures and Valve Steels in Internal Combustion Engines," *London Engineer*, December 12–19, 1910.

DISCUSSION.

Mr. French.

MR. H. J. FRENCH.—In view of the acknowledged importance of further study of the properties of steels at high temperatures and the fact that by far the greater part of published data is confined to carbon steels, the results reported become of particular interest. It is, however, to be regretted that the author has not undertaken a more accurate determination of the changes in elastic properties than is given by determination of yield point by drop of beam.

TABLE I.—TEMPERATURES OF OBSERVED MAXIMUM STRENGTH IN TESTS OF CARBON STEELS CARRIED OUT BY VARIOUS INVESTIGATORS.

Investigator.	Reference No.	Steel Tested.	Approximate Tensile Strength Observed at Room Temperature, lb. per sq. in.	Maximum Tensile Strength Observed at about:		Remarks.
				deg. Cent.	deg. Fahr.	
Rudeloff	1	Siemens-Martin Steel	63 000	230	446	Temperature range for maximum strength: 230 to 300° C. (446 to 563° F.)
Huntington	2	Mild Steel	53 000	250	482	
Perrine and Spencer	3	0.23-per-cent Carbon Bessemer Steel	60 000	240	464	
		0.39-per-cent Carbon Bessemer Steel	72 000	300	572	
National Tube Co	4	0.36-per-cent Carbon Steel	73 000	300	572	
Howard	5	0.09-per-cent Carbon Steel	55 000	295	563	
		0.37-per-cent Carbon Steel	89 000	290	554	
		0.57-per-cent Carbon Steel	120 000	295	563	
French	6 (See Fig. 1)	0.19-per-cent Carbon O. H. Steel	59 000	295	563	
		0.38-per-cent Carbon Elect. Steel	84 000	295	563	
MacPherran		0.10-per-cent Carbon O. H. Steel	50 000	371	700	Temperature range for maximum strength: 343 to 382° C. (650 to 720° F.)
		0.41-per-cent Carbon O. H. Steel	84 000	382	720	
		0.08-per-cent Carbon O. H. Steel (annealed)	48 000	343	650	
		0.51-per-cent Carbon O. H. Steel (annealed)	84 000	330	625	

1. M. Rudeloff.—"Einfluss der Wärme auf die Festigkeitseigenshaften von Metallen" Mitt. a. d. Kgl. Versuchsanstalten zu Berlin 11, (1893), p. 292.
2. A. K. Huntington.—"The Effect of Temperatures higher than Atmospheric on Tensile Tests of Copper and its Alloys and a Comparison with Wrought Iron and Steel." *Journal*, Inst. of Metals, 1912, p. 126.
3. H. Perrine and O. B. Spencer.—"The Strength of Iron at Varying Temperatures." Columbia University School of Mines Quarterly, Vol. 35, p. 194 (1914).
4. G. P. McNiff.—"Strength of Steel at High Temperatures," *Chemical and Metallurgical Engineering*, Vol. 22, No. 14, p. 660 (1920).
5. J. E. Howard.—"Physical Properties of Iron and Steel at Higher Temperature." *Iron Age*, Vol. 45, p. 585 (1890).
6. H. J. French.—"Tensile Properties of Boiler Plate at Elevated Temperatures." *Mining and Metallurgy*, Vol. 158, Section 15 (1920).

The maximum strength of low or medium-carbon steels, within the temperature range investigated by the author, has generally been considered to be in the "blue-heat range," or more specifically in the

Mr. French. neighborhood of 300° C. (563° F.). In this respect there is general agreement, especially between results more recently reported. In view of the fact that Mr. MacPherran reports the highest strength of annealed and likewise rolled carbon steels at considerably higher temperatures, as shown in Table I, the question naturally arises as to the accuracy of temperature measurements.

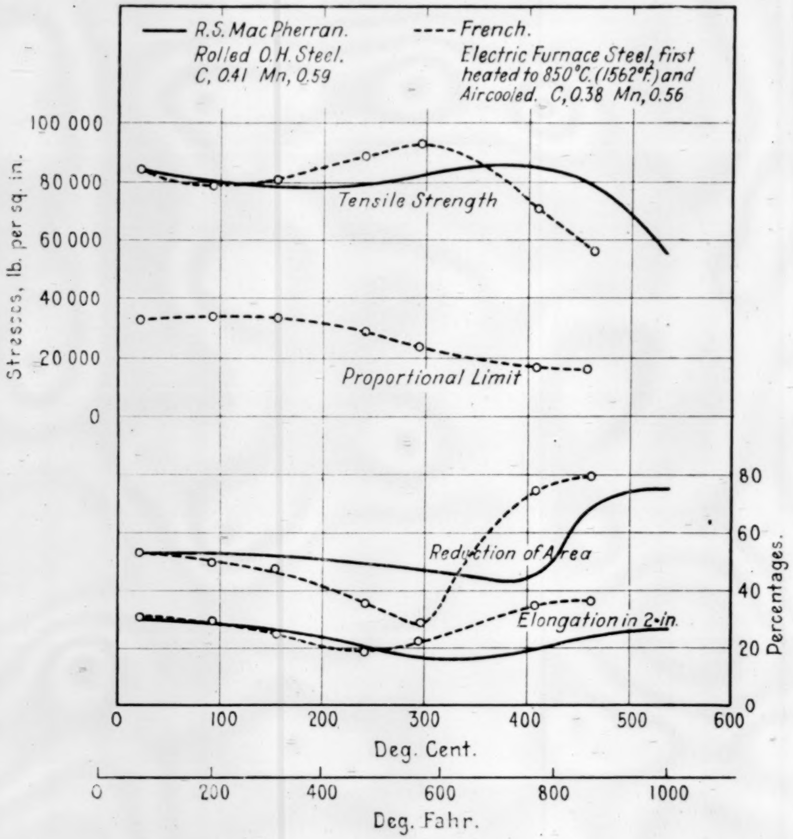

FIG. 1.—Comparison of Tensile Properties at High Temperatures of about 0.40 per cent Carbon Steel as Determined by MacPherran and French.

I am of the opinion that the chosen position for the thermocouple is not representative of the temperature of the test specimen with the method of heating used, and it is suspected that the lower temperature of the sample in large part accounts for the higher temperature range within which the maximum strength is obtained. Comparison of the author's results for rolled carbon steel, of 0.41 per cent carbon,

Mr. French. with results recently obtained by the writer in testing steel of about the same composition is given in Fig. 1. The method of testing used was the same as that described in a report of the tensile properties of several grades of boiler plate at high temperatures.[1]

While the tensile properties of the two steels under comparison are practically the same at room temperature and the general inflections in the physical properties — temperature curves similar — the temperature ranges within which sharp decrease in strength and increase in elongation are first noted are considerably higher in the case of the results reported by Mr. McPherran.

As the effect of temperature on tensile properties of steels is the variable under investigation it would be desirable to have direct experimental data regarding the accuracy of its determination by the method employed, including a survey of variations in the furnace used.

TABLE II.—APPEARANCE OF FRACTURES.

Grade.	270° F.	400° F.	600° F.	800° F.	1000 F.	1200° F.	1400° F.	1600° F.
Carbon Nickel Chrome-Vanadium Nickel-Chrome Chrome-Molybdenum	Stee Gray	Steel Gray	Brown	Dull Light Blue	Dull Blue	Dull Dark Blue	Dull Dark Gray Blue	Dull Blue Gray
30-per-cent Nickel	Light Gray	Light Gray Brown Tinge	Brownish Purple	Greenish Blue	Dark Gray	Dull Purplish Blue	Dul Blue Gray	Blue Gray
14-per-cent Chrome	Steel Gray	Steel Gray	Greenish Brown	Brown	Light Purple	Strong Deep Purple	Dark Deep Purple	Dull Dark Purple
Tungsten—Tool Steel	Steel Gray	Steel Gray	Brown	Light Blue	Purple	Dull Purple	Dull Blue	Blue Gray

Mr. Spooner. MR. A. P. SPOONER.—Owing to the lack of data on the strength of steel at high temperatures such as is covered by Mr. MacPherran's paper, about six months ago, the Bethlehem Steel Co. decided to run a series of tests on various steels, both in the annealed and heat-treated condition. Up to this time only a part of the annealed series is completed, but the data so far obtained confirms those of Mr. MacPherran.

The bars tested were from rolled stock ranging from $\frac{3}{4}$ to 1 in. in diameter; each test bar was cut 16 in. long, threaded on both ends and turned down in the center to a standard 0.505 by 2-in. section. The specimens were heated in a circular electric furnace with a thermocouple inserted, which was connected with a Leeds and Northrup recording pyrometer. The specimens were pulled on a 100,000-lb. Emery testing machine. The yield point was determined by the

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[1] Jeffries and Archer, "The Crystallin Structure of Metals;" *Chemical and Metallurgical Engineering*, May 4th, 1921.

Mr. Spooner. drop of the beam and occasionally checked up with dividers. The arrangement of the specimen and furnace is shown in Fig. 2, the thermocouple being wired to the necked-down section of the specimen and asbestos packing used to close the ends of the furnace tube, which is 1½ in. in diameter. All specimens were held for 30 minutes at temperature before applying the load.

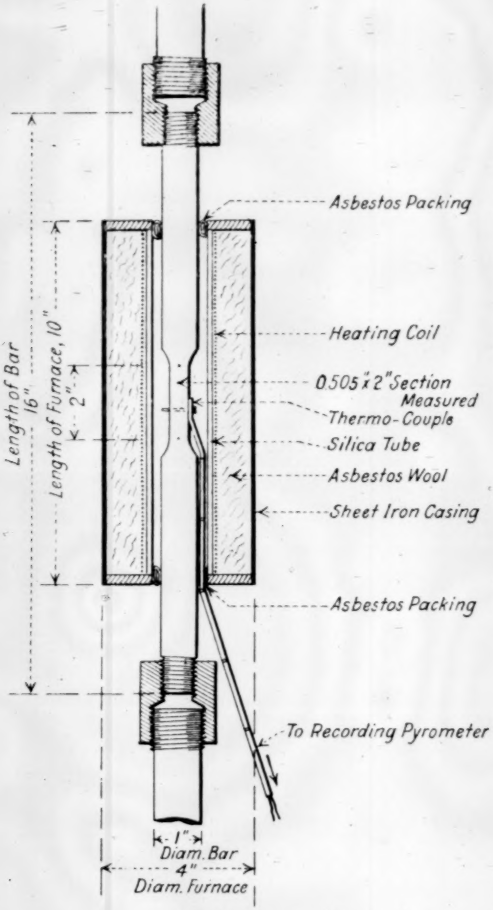
Asbestos Packing
Heating Coil
0.505"x2" Section Measured
Thermo-Couple
Silica Tube
Asbestos Wool
Sheet Iron Casing
Asbestos Packing
To Recording Pyrometer
Length of Bar 16"
Length of Furnace, 10"
2"
1" Diam. Bar
4" Diam. Furnace

FIG. 2.—Arrangement of Specimen in Furnace.

An interesting feature is the color of the fractures of the broken bars. The usual commercial, structural alloy and carbon-steel fractures looked very much alike, but the addition of a large percentage

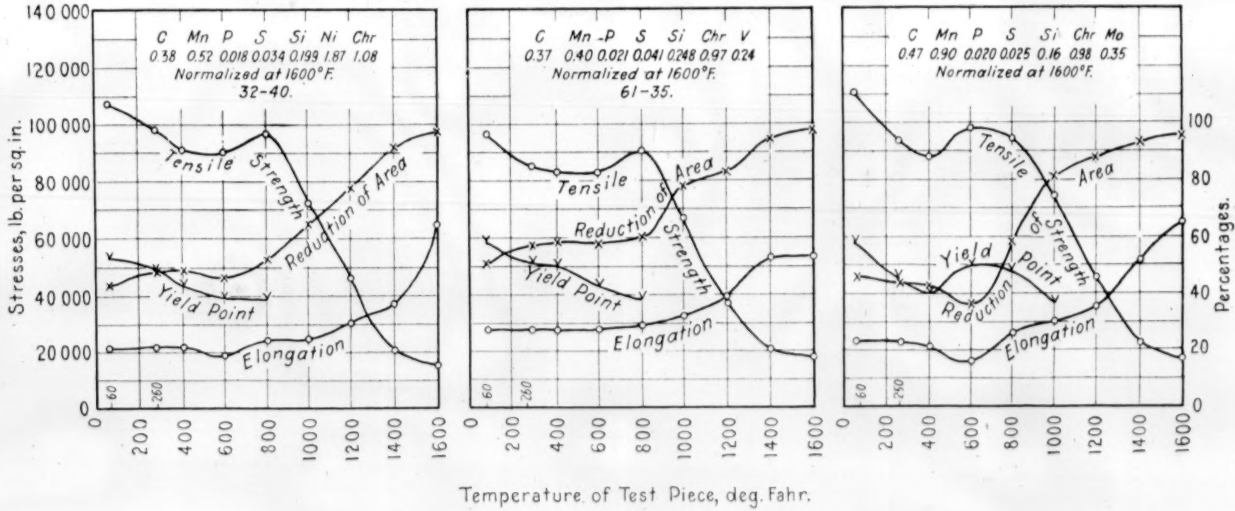

FIG. 3.—Physical Properties of Alloy Steels at High Temperatures.

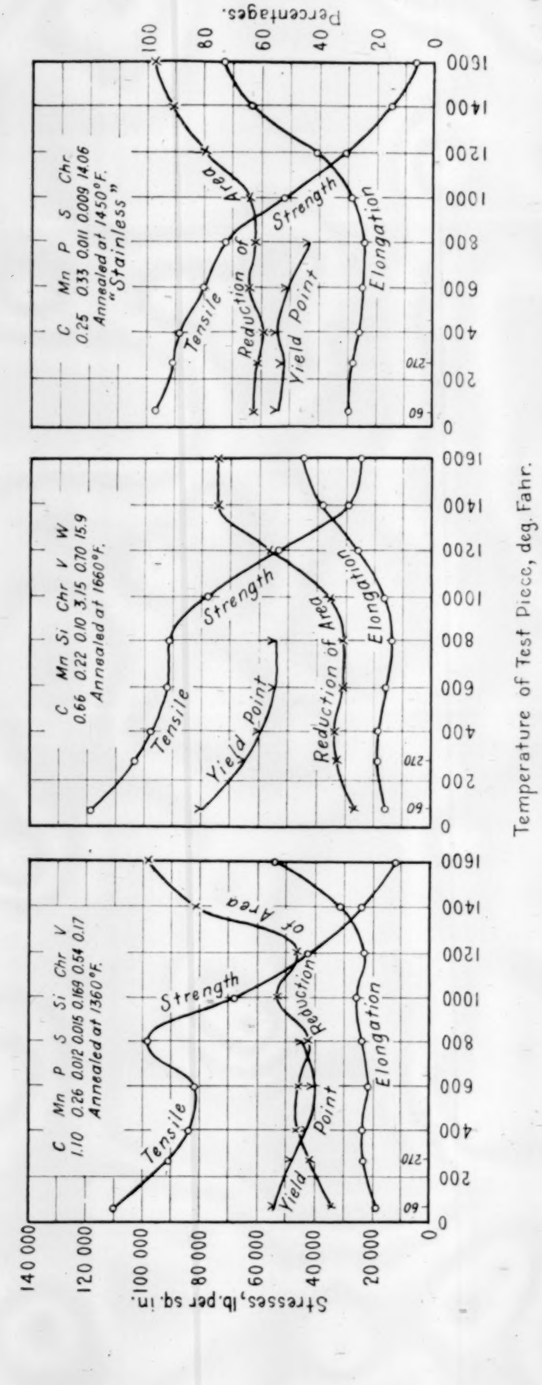

FIG. 4.—Physical Properties of Alloy Steels at High Temperatures.

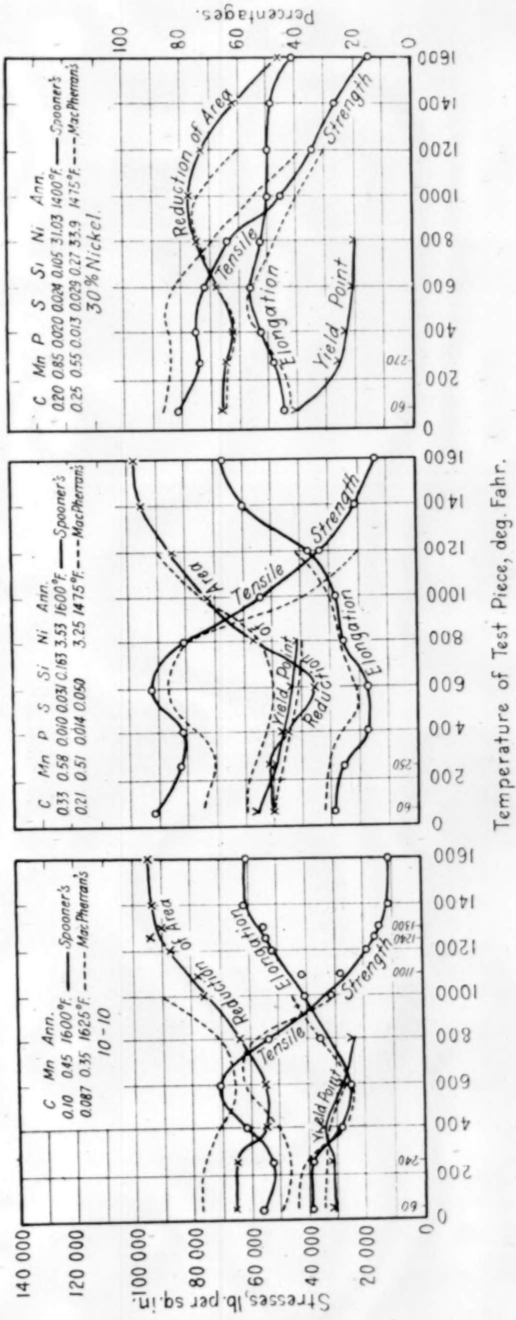

FIG. 5.—Comparison of Test Results with Values in Fig. 4, *a*, *b* and *c* of MacPherran Paper.

Mr. Spooner. of nickel, chrome and tungsten changes the colors considerable as shown in Table II. Stainless steel (high chrome) shows a very distinctive purple in the fractures.

Typical results obtained in heating bars up to 1600° F. in increments of 200° are given in Figs. 3 to 5, inclusive.

All of the commercial structural steels in the annealed condition appear to have a peak tensile strength at 600 to 800° F. which is obtained at the expense of ductility. After passing this brittle point, the tensile strength drops rapidly while the ductility increases in proportion. The high alloy special steels show a tendency to follow, especially in ductility, except in the case of 30-per-cent nickel steel which loses its ductility as the temperature increases and at 1600° F. appears to be burnt. On the grades tested to date no steel shows exceptional values. The tensile strength at 1600° F. varies from 6500 to 25,000 lb. per sq. in. and except for 30-per-cent nickel steel is accompanied by a big increase in ductility, which is valueless in working parts.

In Fig. 5, I have taken the liberty of plotting curves as given by Mr. MacPherran against ours where the chemical composition and treatment make them comparable. The same general tendencies are observed, and the variation in the curves can be accounted for entirely by the difference in composition and treatment.

It is interesting to note that in 1881, Dr. James E. Howard conducted an experiment on a series of simple steel bars ranging from 0.10 to 0.90 per cent carbon which were pulled at Watertown Arsenal at high temperatures, and the curves published in 1888, although not coinciding as well as the later tests, show the same general tendencies. In this early experiment the temperature of the heated bar was calculated by the amount of expansion.

Mr. Holz. MR. HERMAN A. HOLZ.—Mr. MacPherran calls our attention to the necessity of investigating the physical properties of steel at those temperatures at which the material is used in practice, and in particular at the elevated temperatures attained by important elements of internal combustion engines. While the tensile tests undertaken by Mr. MacPherran are of considerable practical importance in the particular field which led to this investigation, it may be well to mention in this connection other interesting investigations of iron and steel at high temperatures which have recently been carried on and which are being continued and extended.

Dr. S. L. Hoyt, in his recent book on "Metallography,"[1] writes a special chapter on the subject of "The Influence of Temperature on the Tensile Properties," in which he reviews some of the earlier work done on this subject by Le Chatelier, Heyn, Rudeloff, and as early as 1888 at the Watertown Arsenal. Dr. Hoyt states in this connection: **Mr. Holz.**

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[1] S. L. Hoyt, "Metallography," Part I, pp. 237–240.

> "As yet there has been little or no work done and published, of this character, on which the rational mechanical treatment of metals at elevated temperatures can be based. The effect of raising the temperature on the properties of metals cannot, as yet, be stated in terms of any definite law; at present it is necessary to treat each class of materials separately However, the behavior may be fairly generally stated by saying that the tensile strength and elastic limit decrease while the elongation and reduction of area increase with rise in temperature. The most important class of materials to be considered here, the steels, furnishes a noteworthy exception to this rule. Rudeloff and others have shown that the tensile strength of steel increases up to about 200 to 300° C. where it reaches a maximum. The elongation drops rapidly from about 30 per cent at room temperature to about 15 per cent at the minimum which lies at about 150 to 200° C. The yield point drops continually, slowly at first and then rather rapidly from 100 to 200° C. On the basis of tensile strength alone a structural steel would appear to improve with rise in temperature. This is misleading, as the increased strength is not available on account of the decrease in elongation and yield point, so that undoubtedly the best combination of properties is that secured over the ordinary ranges in temperature The marked drop in elastic limit and elongation at 200° C., not as yet satisfactorily explained, produces what is known in steel as 'blue brittleness', or excessive brittleness at the temperature corresponding to blue temper colors. On this account it is customary to carry on technological tests on the properties of mild steel at this temperature. These tests are of particular importance in the case of boiler plates, since the plates are not only used at these temperatures but they are weakened by being perforated with rivet holes."

In general, the results of Mr. MacPherran's tests agree quite well with the statements made by Dr. Hoyt and with the results obtained by previous investigators. In regard to tests of boiler plate material at elevated temperatures, the most recent work has been carried on by Mr. H. J. French of the Bureau of Standards, and his results were submitted at the 1920 meeting of the Institute of Mining and Metallurgical Engineers. Mr. French found that at high temperatures—his tests went up to about 470° C.—maximum tensile strength does not correspond to minimum elongation, minimum reduction in area or maximum proportional limit.

Professor H. Edert of Kiel recently described[1] a modification of the Martens mirror extensometer for tensile tests up to 850° C., and while he did not publish any data obtained by means of his apparatus, his paper shows that investigations of the tensile properties of metals at high temperatures are being carried on abroad at present.

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[1] Edert, "Feinmessungen bei Warmzerreissversuchen," *Stahl und Eisen*, April 14, 1921.

Mr. Holz. In 1916 Professor Arnold of Sheffield stated[1] that there was no relation between the hardness of tool steel, as determined by the Brinell or scleroscope method, and its cutting efficiency. The efficiency of a tool, Prof. Arnold said, depends upon the thermal stability of the simple or compound hardenites in hardened steel. The simple hardenite of plain carbon steel has a thermal stability the limit of which is below 300° C., while the compound hardenite of a carbon-tungsten-chrome-vanadium high speed steel, also secured by water quenching, may be rendered stable up to about 700° C. It will be readily appreciated from Arnold's own words that there cannot be a relation between the hardness of steel at room temperatures and its cutting efficiency at the high temperatures attained by a cutting tool in the lathe. If the thermal stability of steel is the power of the hardenites to resist the softening action of heat at varying temperatures, the problem of investigating this thermal stability is solved best by heating the steel progressively to higher temperatures and determining its hardness at those temperatures.

Professor Edwards is at present working on an extensive investigation of the hardness of steels, and especially alloy steels, at temperatures up to 900° C. In order to obtain reliable data, he had to develop first a new method of determining hardness, which had to be suitable for high temperature work and at the same time yield results readily convertible into standard Brinell units. This preliminary development work has been very successful,[2] and it is to be hoped that the results of his investigation on the hardness of steels at high temperatures will be published in the near future, as these data will be of great practical importance in the metallurgy of tool steels. A simple and accurate hardness test suitable for work at high temperatures is one of the greatest needs of metallurgy to-day, especially since other high temperature tests, such as cutting efficiency tests, are extremely complicated, the conditions of testing containing too many variables, some of which—such as the actual temperature of the cutting tool and the uniformity of the material which is being cut—are rather difficult to determine, measure or control. The most extensive investigation of this problem has recently been undertaken in the machine tool laboratory of the University of Sheffield, and the papers published on these cutting tests[3] show the tremendous difficulties encountered, if the results of such research shall be reliable. Naturally, all cutting tests are high temperature tests, and if we can obtain the necessary data by simple hardness tests at the corresponding temperatures, a considerable advance in the art of testing and in the science of metallurgy will be made. **Mr. Holz.**

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[1] Arnold, "Note on the Relations between the Cutting Efficiencies of Tool Steels and their Brinell or Scleroscope Hardness," *Journal*, Iron and Steel Institute, 1916.

[2] Edwards, "A Law governing the resistance to penetration of metals when tested by impact, with a 10-mm. steel ball and a new hardness scale in energy units," *Journal*, Institution of Mechanical Engineers, June, 1918.

[3] Burley, "Cutting Power of Lathe Turning Tools," *Proceedings*, Institution of Mechanical Engineers, 1913, Part 4; *Journal*, Institution of Mechanical Engineers, January, 1920.

Undoubtedly the most interesting research work on iron and steel at high temperatures has recently been carried on in the Physical Institute of the University of Lund, Sweden, under the direction of Dr. Arne Westgren of Gothenburg, and partly covered by his paper "Roentgen Spectrographic Investigations of Iron and Steel," submitted at the 1921 annual meeting of the Iron and Steel Institute.

After Laue had shown, in 1914, that X-rays passing through a crystallin system must cause interference phenomena, and after W. H. and W. L. Bragg, during 1916, made use of these phenomena in developing a method of great practical usefulness by investigating X-rays reflected against crystal surfaces, Dr. Westgren shows the importance of this method of investigation in metallographic research of iron and steel, both at ordinary and elevated temperatures. It would take too long to go here into all details of the very interesting results obtained by Dr. Westgren by a simple and convenient method. The spectrograms taken at high temperatures prove that a fundamental difference exists between the apparent transformation point of iron A_2 and the critical point A_3. No difference has been found in the structure of iron below and above A_2. At A_3, however, the atoms of iron are completely rearranged and the iron passes from one crystal class into another. Consequently, the difference between iron of the α and β states is not of the same kind as that between the α and γ states.

Furthermore, the X-ray spectrographic investigation showed also that the iron atoms of martensite are oriented in exactly the same way as in ferrite. The iron of martensite is consequently identical with that of ferrite, and the difference in hardness between these two structural constituents is not due to the iron but to the carbon present in the martensite. If the orientation of the carbon atoms in the marsite α-iron lattice were known, it should be possible to carry out a theoretical calculation of their influence on the resistance of the lattice against exterior forces. In this connection Dr. Westgren refers to the important work of Born and Landé on the strengths of crystal lattices. Assuming that the forces holding the atoms in a lattice are electric in nature and obey very simple laws, these physicists have been able to calculate the compressibility of certain crystals and have thus theoretically arrived at values which are in good agreement with those

Mr. Holz. determined experimentally. For this reason, X-ray spectrographic investigations, now also carried on in this country, afford great promise in metallographic research. Having once found the space lattices of metals and alloys and the laws for the forces that govern the lattice equilibrium, it ought to be possible theoretically to determine the strength of the systems. In this way problems dealing with the strength of materials, so far soluble only by empiric methods, may be open to theoretic treatment and become based on a rational scientific foundation.

Dr. Rosenhain expresses his belief that the real future advancement of a knowledge of the internal structure of metals can be obtained in the direction of the X-ray spectrum. Professor Edwards says that this method of investigation will greatly help in arriving at the true explanation of why steel is hardened as the result of quenching. Dr. Ruder, after having found it impossible to establish a definite relationship between the magnetic properties of the iron alloys and other elements, such as chromium, tungsten, etc., added, comes to the conclusion that magnetism is not an atomic property but that it is a property of the crystallin structure of the material, and that its solution lies in the direction of the X-ray spectrum. Dr. Zay Jeffries is of the opinion[1] that the advent of the X-ray spectrometer at the present time promises to be about as important an event in the history of metallurgy as was the introduction of the microscope in the latter part of the past century.

It is to be hoped that a number of American metallographists will actively take up this so very promising method of research, suitable for work at ordinary and elevated temperatures, as it is bound to reveal, in a simple and convenient manner, much important information on problems of metallurgy.

Gen. Bixby. GENERAL W. H. BIXBY.—The diagrams that were shown on the screen a few moments ago were quite general in showing that at about 600° or upward the tensile strength was a maximum. If the tensile strength increased steadily, not necessarily uniformly, from the lowest temperature up to 600°; the action would appear quite natural; but in almost every case the tensile strength is less at about 400° F. and it is not only less at 400 than at 600°, but it is less at 400 than at 200 or 250°. I would like to ask if there is any general agreement on the reason why the tensile strength drops between 200 and 600°.

Mr. Gennet. MR. C. W. GENNET, JR.—This paper is interesting and important in furnishing data pertaining to tension tests on steels at high tem-

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[1] Jeffries and Archer, "The Crystallin Structure of Metals;" *Chemical and Metallurgical Engineering*, May 4, 1921.

Mr. Gennet. peratures. If you remember, however, a year or two ago there were some papers presented on the subject of "shattered zones" found in open-hearth steel rails. Those zones occur in the head and occasionally in the base of rails. Presumably the shattering of the structure is in the nature of internal ruptures in the metal, which are produced while the metal is cooling through the range of temperature from that at which it is finished in the mill down to the atmospheric temperature; and it has been further alleged that the shattering, or this internal rupturing, is due to the internal strains set up in the metal as it is cooling. I suggest the importance of obtaining, by some such method of testing as has been described, additional information as to what is the structural condition of steel after it has been stressed at high temperatures. It does not seem to me that tension tests alone satisfy the demand for information on the conditions that may develop in steels when stressed under high temperatures, and I beg to call the attention of the members of the Society to the importance of doing some microscopic work in connection with such tests as have been made and of showing some photomicrographs and etchings of the conditions found.

Mr. Ingberg. MR. S. H. INGBERG.—I want to emphasize the point relative to the temperature measurements employed in Mr. MacPherran's tests and also in Mr. Spooner's tests. My attention was called to it by the fact that the point of maximum strength was at considerably higher temperature than has been found in other investigations, and also that the drop in strength at higher temperatures is not as decided. Some of the difference is possibly due to the method employed in measuring temperature. The thermocouple wire used is of comparatively large diameter, has a rather short immersion in the furnace, and as insulated is in contact with the furnace tube for the greater portion of its length. Under these conditions the thermocouple will receive heat by conduction and radiation from the furnace tube, which will be at considerably higher temperature than the test specimen, due to the high heat losses at the ends incident with metal connections to the grips of the testing machine, and the difference in temperature between thermocouple and test specimen may be quite large. In connection with the fire-resistance work of the Bureau of Standards I made some tests of the compressive strength of steel at high temperatures, and I found considerable difficulty in designing an apparatus that would maintain a uniform temperature over a gage length of about six inches. I interposed load-bearing clay blocks to reduce the excessive conduction that takes place at the bearings and by increasing the heating capacity at the ends was able to get temperature uniformity between the middle and the ends within a few degrees Cen-

Mr. Ingberg. tigrade, which is not very refined, but was sufficient for the purpose. No thermocouple wire heavier than No. 17 (B. & S. gage) was used and the wire nearest the couple was placed in the same region of temperature as the couple for a length of not less than eight inches.

Mr. Spooner. MR. SPOONER.—Our thermocouple was wired to the necked-down section of the bar. We decided to carry out our tests in this manner after we had run a series of experiments to determine the best way to measure our temperatures within practical limits. In our preliminary experiments we had tried inserting the thermocouples in holes drilled in the bars, and other methods of measuring the temperature, and finally decided on the method which we used as being the most practical without going to too much trouble.

Mr. MacPherran. MR. R. S. MACPHERRAN.—I would say that there are two ways to determine the temperature: one is with the thermocouple in contact with the outside of the specimen at the center of its gage length and the other by inserting it *in* bar *outside* the gage length. If the thermocouple is in contact with the surface of the specimen at the center, the test specimen cannot be hotter than the couple. If it is inserted in the specimen outside the gage length the couple cannot be hotter than the specimen. The possible error of the first method is to get too high temperature readings and of the second method to get too low readings. We looked into these two methods of taking temperatures carefully and decided on the former system.

It is possible that the higher temperatures found by Mr. Spooner and ourselves are due to the placing of the couple. It would seem to me, however, that there is more to be said in favor of the system we adopted than for the one requiring the insertion in the test specimen of the thermocouple junction. It is very difficult to maintain a constant temperature for considerable distances in the furnace tube, and we believe that the temperature should be taken as near as possible to the point of rupture. It was very gratifying to us to note the close agreement between Mr. Spooner's results and our own. The work was carried on independently by both parties.

It would be interesting to find some method of testing the fatigue value at various high temperatures and we should like to call this to the attention of those doing work along this line.

Mr. Speller. MR. F. N. SPELLER (*by letter*).—Some further data on this subject will be found in a discussion by the writer of a paper by White and Wood on "Failure of Boiler Tubes."[1] The tests referred to were carried up to 1100° C. It was found that the tensile strength of steels of various carbon contents bore the same relation to each other at higher

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XVI, Part II, p. 112 (1916).

Mr. Speller. temperatures as they have at normal temperatures. Generally speaking, the tests we made on soft steel show the same results as those reported by Mr. MacPherran.

Mr. MacPherran. Mr. R. S. MACPHERRAN (*Author's closure by letter*).—In reply to communication of Mr. French, I would say that the curves shown in our Figs. 1 and 2 to which he refers are of unannealed carbon steel and have too few tests between the temperatures of 600 and 800° F. to be regarded as representative at this range. As stated in our paper, our conclusions were based on the curves of annealed carbon steels, Figs. 3 and 4. It was from these we drew our item No. 2 that "the maximum tensile strength for rolled carbon steel, annealed, occurs between 600 and 650° F." If Mr. French will plot his results against these curves, he will find a much closer agreement.

A series of tests were made with one thermo-couple touching the outside of the center of the test specimen as in our tests, and another couple adjusted so that the point was in exact center of hole drilled through the specimen in the same horizontal plane as the point of the first couple. To protect the point of this second couple, the hole was then plugged with asbestos. The two couples therefore indicated the temperatures at surface and center of test specimen. To emphasize the difference between center and outside, we used a test specimen 0.75 in. in diameter in place of our regular 0.505-in. diameter. Three sets of readings were taken at temperatures in excess of 500° with the result that the center of test specimen was found to be 22 to 36° F. below the temperature of the outside of the bar. With a 0.505-in. bar, this difference would of course be less. As the area represented by the outer layers is much greater than that represented by the center, we believe the location of our thermo-couple gives a better indication of the average temperature of the test specimen.

The testing of the hardness of tool steels at high temperatures as described by Mr. Holz is very interesting as is also his reference to the X-ray investigations. These are both fields which should be of great interest to our research laboratories.

The suggestions of Mr. Ingberg as to size of couple wire are appreciated and we will try out a couple of the smaller wire.

In conclusion, would say that we are glad to note the amount of discussion and friendly criticism of our results and would add that arrangements are being made to have this line of work continued to cover the fatigue of steels at high temperatures.

A TEST FOR SHOCK STRENGTH OF HARDENED STEEL.[1]

By C. E. Margerum.

Many steel objects intended to resist impact are hardened and tempered. The degree of hardening aimed for in producing any particular object has been determined entirely by experience. Brinell, Scleroscope, and other tests assist one in attaining uniformity of product, but not in determining how hard an object should be. Charpy, Izod and similar impact tests which determine the energy consumed in bending and rupturing test specimens, are not adapted to hardened steels because the number of foot-pounds is diminished both by an increase of hardness and by defects of the steel. Thus a property which is desired has the same effect as one which is most objectionable, and consequently the result of such a test of hardened steel has no intelligible meaning.

Aside from any other disqualification of this form of test, it is inapplicable because it determines amount of energy and not strength. The word "strength" is used in the same sense as it is when one speaks of tensile or compressive strength, that is, the intensity of the property by which the material resists the application of force which tends to break or deform it. Its magnitude can be expressed in pounds but not in foot-pounds. When we have found the amount of energy required to break a bar, we have as much information as to the strength of the bar as one would have of the greatest depth in a pond if he had measured the amount of water required to fill it, and the surface area after it was full, but had no means of taking soundings.

As strength is the essential quality in steel hardened to resist impact, it is almost necessary, if one is to make an effective study of material for this service in an experimental way, to have facilities for determining the strength of specimens of hardened steel when subjected to shock loads. Appliances for determining hardness, ductility, and other properties are part of the usual equipment of physical laboratories, but it was necessary to design new apparatus to determine the strength under impact. The test to be satisfactory should be certain, definite, simple, rapid, and at least moderately sensitive. The testing device must be capable of testing the hardest and strongest steels that can be produced.

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[1] Published by permission of the Secretary of the Navy.

The apparatus devised for a test to meet these conditions is illustrated in Fig. 1, which is intended to be self-explanatory. The maximum load sustained by a test specimen before breaking under the blow from the hammer is recorded by the impression made by a 10-mm. steel ball in a calibrated record bar. The use of mechanisms such as hydraulic devices, levers, springs, etc., in the weighing system was precluded by the errors which would have been caused by their inertia and elasticity. In addition to the ball and record bar the device consists of a hammer capable of delivering a blow at any predetermined velocity up to 32 ft. per second, a plunger to carry the force of the blow to the ends of the test specimen at spots $\frac{7}{8}$ in. from its center, a bearing piece under the center of the span to transmit the pressure to the 10-mm. ball without undue local deformation of the test specimen at this point, and means for supporting the various pieces in their proper positions up to the moment of impact and to prevent overrunning of the plunger. The specimen is tested as a beam in order to reduce the pressure per square inch on the contacts, as no material which could have been used in the construction of the device would have been stronger than that which it was intended to test.

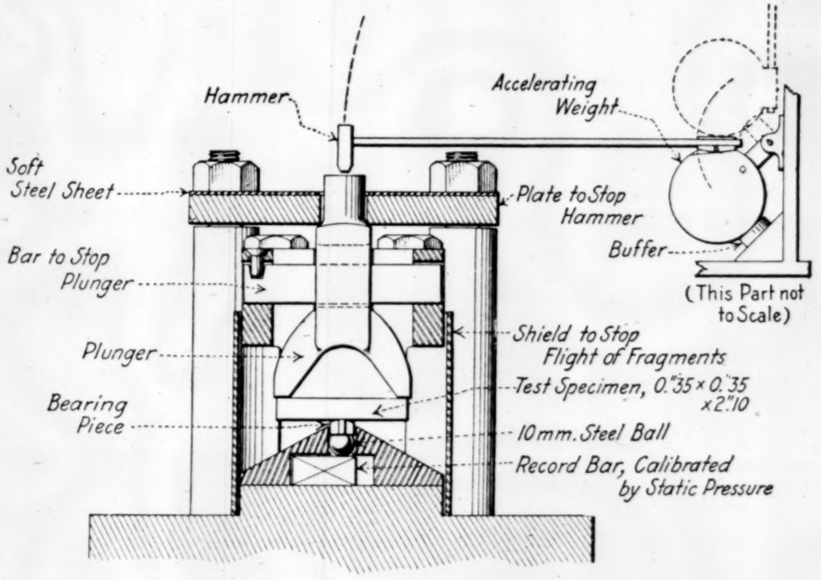
Hammer
Accelerating Weight
Soft Steel Sheet
Plate to Stop Hammer
Buffer
Bar to Stop Plunger
(This Part not to Scale)
Shield to Stop Flight of Fragments
Plunger
Test Specimen, 0.″35 × 0.″35 × 2.″10
Bearing Piece
10 mm. Steel Ball
Record Bar, Calibrated by Static Pressure

FIG. 1.—Apparatus for Determining Strength of Hard Steel Under Impact Loading.

The record bars are cut from a large chrome-nickel forging which has been quenched and drawn to about 270 Brinell. In this way a number of bars may be secured in which no variations of hardness can be detected. The bars are $\frac{1}{2}$ by $1\frac{1}{8}$ by 10 in. and each will record about 200 impressions arranged in six rows, three on each side of the bar. As a preliminary to calibrating the bars they are Brinelled at four points on each edge and at both ends on both faces. The hardness having been found to be uniform, a 10-mm. ball is placed between two bars and a load of 7500 lb. applied with a tension testing machine. Other impressions are made with loads at increments of 1000 lb. up

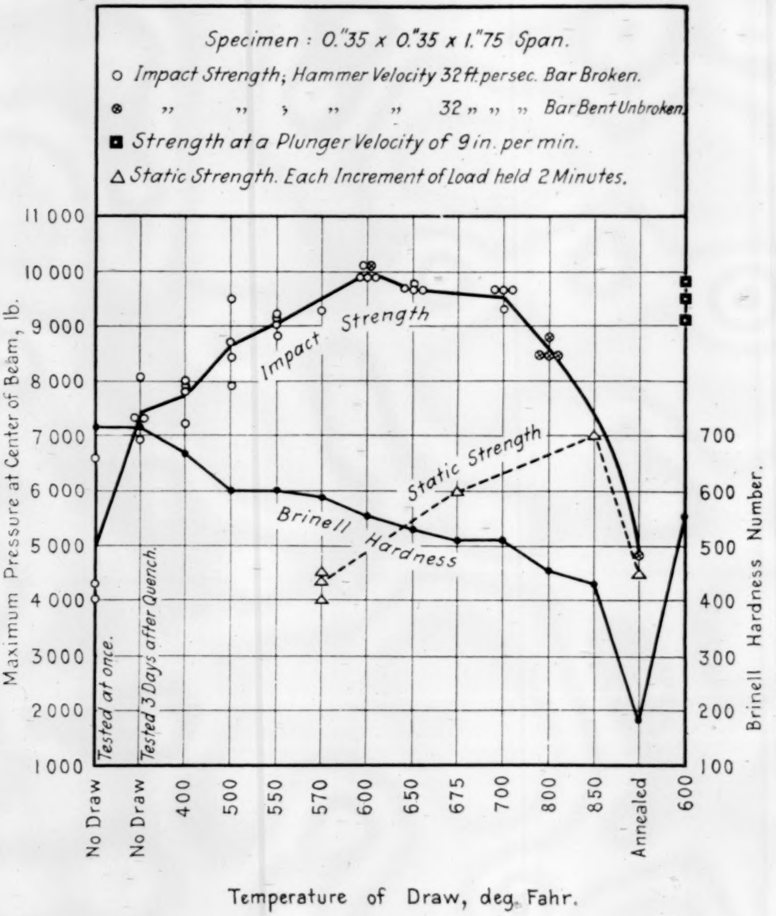

FIG. 2.—Impact Strength Test on a Carbon Tool Steel Containing 1.08 per cent Carbon. Other Tests Included for Comparison.

to 12,500 lb. The hydraulic Brinell machine is used for loads of 3000 kg. and under. Two impressions are made for each load and the calibration curve used in determining the stresses developed in the tests is made by plotting the diameters of the impressions produced by these measured loads.

Each test makes an indentation in the record bar which is a permanent mechanical record of the breaking load, which may be read at any time and checked as often as desired. The diameters of the impressions are read in the same way as for the Brinell test, using the microscope designed for that purpose. Readings are made to 0.01 mm. by dividing the 0.01-mm. divisions of the microscope scale by eye. By giving the record bar a polished surface and using a plane glass illuminator to secure normal illumination, the impressions are clearly outlined, and reading to 0.01 mm. is quite practical. Check readings over a series of impressions vary not more than 0.02 mm. from diameters previously determined. As a difference of 0.02 mm. in the measurement of diameters of impressions in the record bars we are using corresponds to less than 1 per cent of the total pressure for all loads greater than 7000 lb., it is considered that this degree of accuracy is adequate.

The results of tests are reported in pounds pressure required to break the standard test specimen of 0.35 by 0.35 in. square and 1.75-in. span. In comparing samples representing varied treatments or compositions the results are satisfactory in this form, since a numerical expression of the strength of the material is the objective.

Fig. 2 shows results of impact strength tests made with the apparatus described, and determinations of breaking load of similar bars on which the pressure was applied and measured by a static testing machine of the usual type. The test specimens were cut from a single bar of ½-in. hot-rolled carbon tool steel containing 1.08 per cent carbon. They were heated in a lead bath to 1480° F., quenched in water, and drawn in a bath of solder to the temperatures indicated. During treatment they were held in racks which kept the bars separate so as to allow access of the metal baths and water to each bar equally. These precautions to secure uniformity of treatment were successful, at least to the extent that the Brinell hardness of the bars was uniform throughout each group. The erratic results on the undrawn bars and on those drawn at low temperatures are typical of a condition common to all the steels that have been examined. That this may be due to internal strains or some other unstable source of weakness, is suggested by the absence of very brittle bars in the half of the undrawn set which had three days of rest between treatment and test. Lack of tensile strength in the harder samples is indicated by cracking around and in Brinell impressions in all specimens of this lot that were not drawn at 500° F. or higher temperatures. One of the fields of usefulness of the test for impact strength will be found in investigating these conditions, but any expression of definite opinion in the premises at the present time would be premature.

Tests of chrome-nickel steel, part of a series on the influence of the velocity of test, are shown in Fig. 3. This investigation has not been carried far enough to reach conclusions as to steels in general, but where the breaking strength of any of the samples examined was different for different velocities of impact, the higher velocity gave the greater strength. This result was not unexpected in view of the results of notched-bar impact tests by Charpy, Fremont, Hadfield, and others, in which the energy absorbed by certain samples of high-grade steel was somewhat greater at higher than at lower velocities of the blow. Our own experiments were carried only far enough to assure ourselves that minor variations from a prearranged velocity, such as would be caused by friction or other conditions of operation, would have no material influence on the results. The last group of bars on the right of Fig. 3 is an extreme example of the influence of speed of impact. These bars bent enough to use up the energy of the blow and broke when the hammer had come to rest or had started to

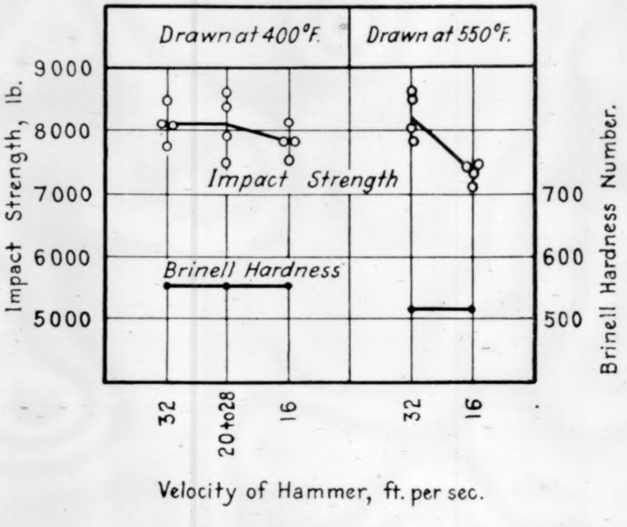

FIG. 3.—Impact Strength Tests on a Chrome-Nickel Steel at Various Velocities of Impact.

rebound. In the practical operation of the test a standard velocity of 32 ft. per second is employed, which is enough to force the plunger down the full amount of its travel (0.15 in.), regardless of the strength of the test specimen.

There may be some uncertainty as to whether an impression made in 1/3000 of a second will be as large as one produced by the same pressure from a tension testing machine in which the pressure is maintained for several seconds. The deformation of metals by pressures of momentary duration has been carefully studied in connection with the use of crusher gages for determining the gas pressures produced by explosions. The conclusions reached apply equally to the weighing device used in the shock strength test, as the principle is the same for both. To quote from Charpy and Cornu-Thenard:[1]

"Messrs. Sarrau and Vieille in their celebrated experiments on the measurements of explosive pressures, found that the deformations produced on the crushed cylinders, per given pressure, remained practically identical even when the rate of applying the pressure varied from 0.1 to 0.0003 second." G. Charpy "has shown that in order that the results of the tests of powder pressures by crusher gages should be influenced to an appreciable extent, it was necessary that the average duration of the deformation should vary from 2 or 3 minutes to 1 second. Under such conditions the variation reached 8 to 10 per cent of the amount of the pressure."

In view of the findings of these investigations, and of the long established use of crusher gages as the basis of calculations in ordnance design, it was not considered necessary to construct special apparatus to investigate further; but experiments with the apparatus at hand demonstrate that any error from variation of the time interval in making shock strength tests with the present record bars is too small to affect the readings appreciably. These experiments will not be described in full because of lack of space. One was the breaking of test specimens in the tension testing machine so that the loads, which were applied at various rates, could be measured both by the identation of the record bar and on the beam of the testing machine. The results checked within the limits of sensitiveness of the testing machine. Another experiment was the breaking of a series of bars using a decreased energy of blow so that some of the bars would break and the hammer would rebound from others. The duration of the effective pressure was from two to five times as great for the unbroken bars as it was for those which broke, but no effect of this greater time could be seen from the results.

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[1] *Journal of the Iron and Steel Institute*, Vol. XCVI, No. 11, 1917.

It is believed, therefore, that for all practical purposes the figures obtained by the method used in this test represent the true strength in pounds. In this connection attention is called to the wide difference shown in Fig. 2 between the loads which the test bars supported continuously, those which they supported under a gradually applied load, and those which they supported under impact. Any error resulting from the limited duration of the pressure on the ball would act to give results less than the true values.

Inertia could affect the results in either direction. The combined weight of the ball and bearing piece, the only moving parts in the weighing system, is 7.8 g. (0.017 lb.). At an impact velocity of 30 ft. per second the ball travels into a record bar of 270 Brinell hardness at the rate of $5\frac{3}{4}$ ft. per second until the limit of proportionality of the test specimen is reached. Even the slight weight of 7.8 g. with a velocity of $5\frac{3}{4}$ ft. per second, corresponding to a fall from 6.2 in., gives a pressure of 350 lb. on impact with these record bars. This illustrates the difficulty of avoiding disturbing effects from inertia of the parts of the apparatus in testing for impact pressures. Except on extremely brittle bars, there is no error from this cause in the form of test we have adopted, as the velocity of the ball dies down during the slight deformation of the bar just before it breaks.

The absence of springs, levers, and similar devices limits the factors which can affect the results of the test to three things which are easily controlled. These are: (1) the dimensions of the specimen and of the span; (2) the velocity of the blow; and (3) the calibration of the record bar. The regularity of the results when a testing series of bars of nearly uniform strength is shown by the carbon-steel bars drawn at 550° F. and higher, in Fig. 2.

It might be interesting to go into the conclusions reached from information disclosed by this test, but that would be outside the purpose of this paper, which is to describe the method and apparatus.

The method of test is applicable to ductile metals also by the use of notched bars of the standard form, such as used in determining the work of rupture.

Acknowledgment is made to Mr. W. A. Henley, Metallographist at the Naval Ordnance Plant, for valued assistance in conducting the investigation.

MAGNETIC TESTING OF SPRINGS.

By T. Spooner and I. F. Kinnard.

The pioneer work of C. W. Burrows along the line of magnetic analysis has opened up many possible applications. One which promises to be quite profitable is the application to large heat-treated steel springs. It has been thoroughly demonstrated that there is a close correlation between magnetic and other physical properties of materials as was clearly shown by papers presented before the Society two years ago. In order to make the application, it is only necessary to devise simple and rapid testing equipment. This paper will describe such equipment together with a summary of the test results on a considerable number of springs.

Test Methods.

Magnetic analysis performs two distinct functions:

1. The detection of flaws and inhomogeneities. This is accomplished most easily by one of Burrow's leakage methods.

2. The determination of the physical properties as deduced from a measurement of the magnetic properties such as maximum induction, B_m, retentivity, B_r, and coercive force, H_c.

In order to apply these methods to springs, an apparatus was devised which could be used for both kinds of tests. A more detailed description of the test methods will be given in a later paragraph.

Testing Apparatus.

The springs were of the helical type, having an outside diameter of about 6 in. and a coiled length of about 15 in. The spring material was either 1 or $1\frac{1}{8}$ in. in diameter.

Fig. 1 shows the apparatus with a spring and exploring coil in position. The magnetizing coil consists of 10 U-shaped copper bars, arranged in a circle with the openings up. A cap fitting on the top when the spring is in position connects these U-shaped pieces in series giving a magnetizing winding of ten turns, which causes flux to pass around the spring parallel to the individual turns. The arrangement is magnetically nearly the equivalent of a long rod in a solenoid. The spring itself rests on a base of babbit metal in which was cast a tapering extension piece of spring material bent to the same radius as the spring, the effect being to cause a less sudden tapering off of the magnetic flux. This base in turn rests on a series of balls in a circular groove, thus forming a turntable which is revolved by a belt connected to a reversible D.C. motor.

A pair of exploring coils of 100 turns each mounted on a brass holder and connected opposing could be slipped on the end of the spring and run down as the spring revolved.

In order to magnetize the spring, a current of 300 amperes was required for a magnetizing force of 100 gilberts per centimeter. This was supplied by a D.C. generator. The inductions were measured by means of a ballistic galvanometer for Method A, and a Grassot fluxmeter for Method B.

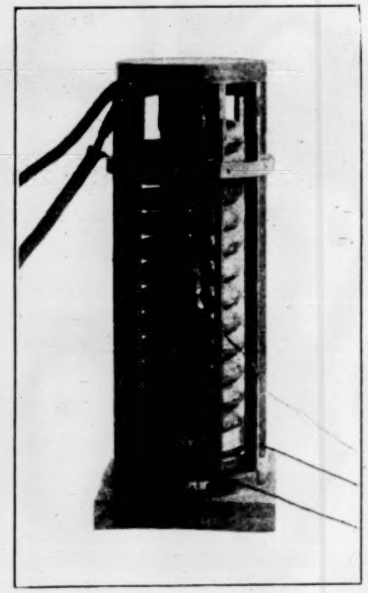

FIG. 1.—Apparatus Assembled for Test.

TEST PROCEDURE.

Test for Flaws.—In order to test for flaws and inhomogeneities the exploring coils were connected together in series opposing to the galvanometer by closing switch S_7 (Fig. 2) to position 1 and closing switch S_6 to position 1. The magnetizing current of 300 amperes was applied to the magnetizing coil and the motor started by means of switch S_4. As the exploring coil traveled down the spring any change of uniformity was indicated by a movement of the galvanometer. S_4 was then reversed and the exploring coil brought back to the top of the spring. Points showing large or sudden deflections of the galvanometer were indicated by chalk marks on the spring and checked for both directions of spring rotation.

Test for Hysteresis Data.—To obtain the three points on the well-known hysteresis loop, B_m, B_r, and H_c we have:

$$B = KD$$

where B = induction in gausses;

D = the deflection of the fluxmeter when the magnetizing current is reversed; and

$$K = \frac{M\ I_{cal} \times 10^5}{A\ N_2\ D_{cal}}.$$

in which M is the mutual inductance in millihenries; I_{cal}, the calibrating current; A, the cross-section of spring in square centimeters; N_2, the turns of exploring coil = 100; and D_{cal}, the deflection of fluxmeter upon reversal of I_{cal}.

To obtain B_m, S_2 (see Fig. 2.) is closed and S_1 reversed with millivoltmeter MV maintained at 300 amperes (100 gilberts per centimeter). For B_r, S_1 is opened. The reading of the fluxmeter gives $\triangle B$. $B_r = B_m - \triangle B$. For H_c, S_2 is opened and S_1 thrown from position 1 to position 2 with R_2 adjusted so that B is reduced nearly to zero. By opening S_3 the value of H may be read more accurately from millivoltmeter mv. Two points may be taken near the zero value of B and H_c interpolated or with the particular set-up used, B and H varied rather slowly near the zero point of B and mv could be read as B passed through zero.

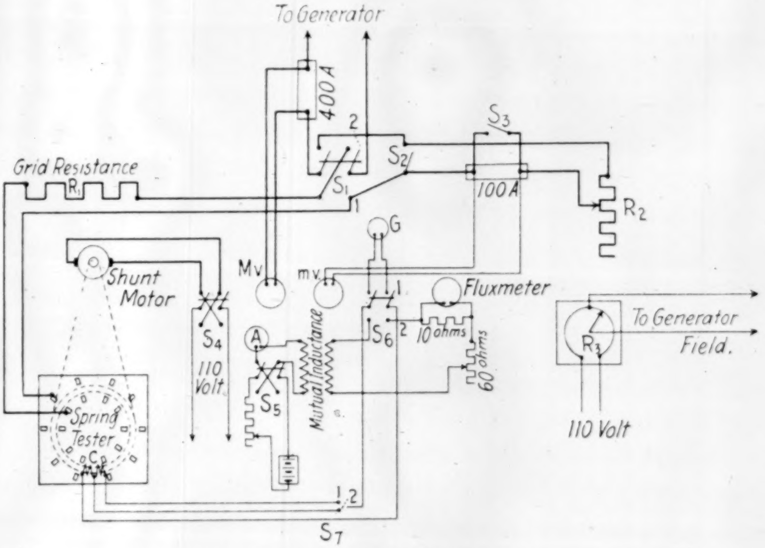
To Generator
400 A
2
S_3
S_2
Grid Resistance
R_1
S_1
1
100 A
R_2
G
Shunt Motor
Mv
mv
1
Fluxmeter
S_4
110 Volt
A
Mutual Inductance
S_6
2
10 ohms
60 ohms
S_5
Spring Tester
C
R_3
To Generator Field.
110 Volt
1
2
S_7

FIG. 2.—Diagram of Connections.

If a suitable generator is available all of the primary connections and R_2 may be done away with and the current changes obtained by means of a special reversing field rheostat R_3. This method was used quite successfully for some of the preliminary tests with an 800-ampere, 60-volt generator.

TEST RESULTS.

Test for Flaws.—Several hundred carbon springs and a few alloy springs were tested by the leakage method and a few of those which showed especially poor uniformity were laid aside for special investigation. Also a number of springs which had been in service for some time were tested.

The springs which gave especially large galvanometer disturbances were ground and polished on the surface and tested by means of the scleroscope. In general, an agreement was found between the magnetic soft and hard spots and the scleroscope readings. The differences were small, however, and the scleroscope readings were difficult to get, due to the rounded surface of the springs. Also, in some cases, the surface of the springs showed indications of decarbonization due to the heat treatment which gave low scleroscope readings. No transverse cracks or fissures were found by the magnetic test either in the new or used springs.

All springs showed more or less lack of uniformity but so far as could be determined none of the inhomogeneities were of a serious nature. Consequently, the leakage test was abandoned in favor of the hysteresis test.

Hysteresis Results.—Some 30 or 40 carbon springs were tested for B_m, B_r and H_c. About 700 silico-manganese steel springs and about 40 molybdenum steel springs were tested. A sample was cut from the end of each of the silico-manganese springs, the surface ground and a Brinell test made.

The carbon springs had the following characteristics:

	MAXIMUM.	MINIMUM.	MEAN.
B_m, kilogausses	14.1	13.1	13.6
B_r, "	7.2	6.4	7.0
H_c, gilberts per cm	19.3	16.3	17.3

Six hundred silico-manganese springs had the following characteristics:

	MAXIMUM.	MINIMUM.	MEAN.
B_m	16.9	15.1	15.9
B_r	13.4	7.86	10.1
H_c	17.8	10.3	14.7
Brinell Hardness	418	277	336

Thirty-six molybdenum springs had the following characteristics:

	MAXIMUM.	MINIMUM.	MEAN.
B_m	17.3	15.3	15.9
B_r	11.7	8.8	9.7
H_c	18.8	15.8	17.2

Of the 600 silico-manganese springs 18 were selected as follows and given a specially careful test:

Five with low B_m, B_r and H_c;
Five with high B_m, B_r and medium H_c;
Four with medium B_m, B_r and H_c;
Four with high H_c and average B_m and B_r.

The magnetic properties for these springs were plotted against Brinell hardness as shown in Fig. 3.

Furthermore five of these springs were especially selected as covering the widest range of variation of magnetic properties among the entire lot tested. These five in addition to the magnetic and Brinell tests were examined microscopically and then broken in a special testing machine which alternately stretched and compressed the springs combined with a rotary motion. The test results were as given in Table I.

TABLE I.

No.	B_m	B_r	H_c	BRINELL HARDNESS.	REVOLUTIONS TO FRACTURE.
1108	15.1	7.9	10.3	310	7 000
1043	15.7	9.0	11.3	300	13 831
511	15.8	9.9	17.8	364	13 433
856	16.1	10.7	16.2	364	12 342
642	16.9	13.2	13.6	412	79 300

Without reference to anything but his photomicrographs, the metallographist characterized the springs as shown in Table II.

TABLE II.

No.	GRAIN SIZE.	STRUCTURE.	HARDNESS.
1108	Large	Pearlitic-Sorbite	Very soft
1043	Fairly large	" "	Soft
856	Normal	Sorbite	Hard
511	"	"	"
642	Fine	Troostitic-Sorbite	"

DISCUSSION OF RESULTS.

As mentioned above no results of sufficient value to warrant further work were obtained from the leakage tests. This was due, in a large measure, perhaps, to the fact that the material as supplied by the manufacture, was a fairly uniform product. Also the greatest stress occurs in the spring near the ends and satisfactory tests could not be made closer to the end than about 1 turn, due to the fact that the galvanometer would go off scale.

The hysteresis data, however, gave results which were very promising. An analysis of the results showed that B_r was the most sensitive and certain indication of the quality of the spring as indicated by Fig. 3. It will be noted from this figure that there seems to be a critical point corresponding to a Brinell hardness of about 360. It will also be noted that there may be in general two values of Brinell hardness corresponding to a given value of H_c. The physical hardness may be determined approximately from the values of B_m or B_r, the latter being the more sensitive as the slope of the curve indicates. It may be noted that one sample at a hardness of 352 does not line up with the curves. It is probable that the hardness is in error and should have been about 380 as all three magnetic properties would then fit the curves.

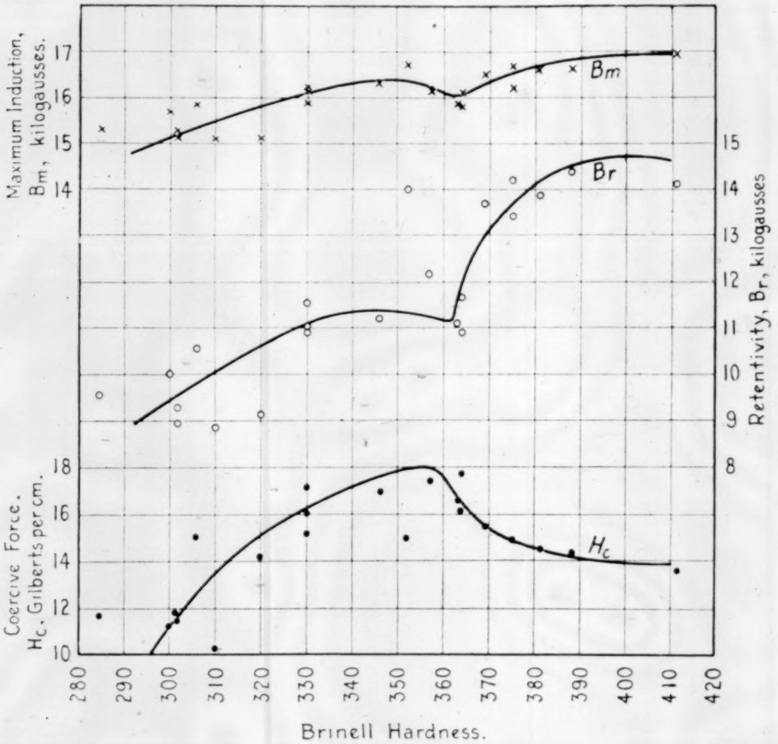

FIG. 3.—Relation between Magnetic Properties and Brinell Hardness.

The five springs listed in Tables I and II show remarkable agreement between magnetic properties, Brinell hardness and microstructures. In Table I, the springs are arranged according to B_r and Brinell hardness. This arrangement checks that of the metallographist's Table II with the exception that springs Nos. 511 and 856 are interchanged. This is not serious, however, since the magnetic properties are nearly identical and the Brinell hardnesses are identical. A general agreement between the physical properties and the breaking revolutions will also be noted.

After the five springs were tested the fatigue machine was somewhat modified and some of the other 18 springs tested. The agreement was fairly good.

That the points of Fig. 3 line up so well is rather surprising considering that there are at least three variables: namely, chemical compositions, quenching temperature, and drawing temperature. No detailed studies were made of the carbon or molybdenum springs but the comparison between the magnetic properties is interesting.

In order to establish magnetic criteria for determining the physical properties of springs, it is possible to obtain approximate results on straight bar test samples of the same composition and cross-section as the spring material. These may be heat treated under various conditions and then tested in a Burrows or Fahy permeameter. Such results should be used with caution, however, as the large mass of material in the spring will alter the quenching conditions producing a less drastic quench than would be obtained with the sample. It is preferable in order to establish magnetic data to give a standard spring the proper heat treatment and determine the magnetic properties from it.

The chemical compositions of the spring materials is not given as it would be of interest only for springs of the same size and shape, heat treated for the same conditions of use.

Commercial Testing.—The apparatus as used by us was rather crude and inconvenient but fair speed was obtained for the hysteresis tests. With one man operating the switches, another reading the meters, and a third handling the springs, 135 were tested in 6½ hours or about 3 minutes per spring. This involved the determination of B_m, B_r and H_c for each spring and included calibrating the fluxmeter. By using a mechanically operated switch controlled by push buttons, one man could be eliminated. The operation could also be speeded up in other ways. For instance about half the time was consumed in getting the exploring coil to the center of the spring and off again, as the driving motor was geared down so that it would be suitable for uniformity tests.

CONCLUSIONS.

From the results of these tests the following conclusions may be drawn:

1. The leakage method of test offers little promise of usefulness for this class of material unless the supplier is furnishing an especially

non-uniform product, particularly since it will not detect longitudinal seams or cracks.

2. The hysteresis method of test furnishes a ready commercial method of checking the quality and heat treatment of the finished springs.

3. The retentivity, B_r, furnishes the most satisfactory indication of the physical condition of the material. Moreover, this test is an extremely simple one to make.

4. This method of test gives both the spring user and the spring manufacturer a quick and simple method of determining the quality of the completed springs without destroying any material.

5. The magnetic values given in this paper can be applied only to material of the same cross-section and chemical composition. With the same chemical composition and heat treatment, quite different physical and magnetic properties would be obtained for material having a much different cross-section.

Acknowledgments.—In conclusion we wish to state that this investigation was suggested by Mr. T. D. Lynch. The physical tests were made under the direction of Mr. W. J. Merten, and the metallographic results were furnished by Mr. R. E. Bedworth.

SOME FAILURES OF CAST-IRON WHEELS.

By H. J. Force.

The cast-iron wheel has a marvelous history. The general public knows little of the wonderful progress of the chilled-iron wheel industry; nevertheless, it has grown steadily with the railroads and to-day the commerce of the nation depends upon it. Approximately 26,000,000 chilled-iron wheels are now in use in the United States and Canada, serving under freight cars, passenger coaches, refrigerator cars, engine tenders, city street cars, interurban cars and electric locomotives. Eighty to ninety per cent of all the equipment in the United States and Canada is equipped with cast-iron wheels. The annual production in the United States is approximately three million wheels, some of which are exported to France, Russia, Italy and other foreign countries. A large proportion of the total production is required for repairs.

Table I.—Wheels Worn Out in Service.
(All values in per cent.)

Mark.	Cast.	Total Carbon.	Graphitic Carbon.	Combined Carbon.	Phosphorus.	Sulfur.	Manganese.	Silicon.
A.........	9-20-15	3.31	2.32	0.99	0.360	0.154	0.49	0.70
B.........	6- 2-16	3.53	2.77	0.75	0.308	0.136	0.66	0.73
C.........	7- 2-13	3.17	2.18	0.98	0.304	0.155	0.55	0.65
D........	8-24-12	3.08	2.15	0.93	0.260	0.122	0.43	0.59

It may be asked why chilled-iron car wheels have proven so satisfactory, when other parts of car, track and structure have been superseded by other and more expensive materials. We believe that this is due to the character of the metal, for no other material has been able to make any serious inroad on the chilled-iron wheel for the past seventy years.

It is the object of this paper to point out such recommendations and changes as are thought to be necessary in the chilled-iron wheel. It is well known that during the past few years railway cars have been loaded to greater capacity; heavier equipment has been placed on many lines; many roads are using rails much heavier than a few years ago; roadways are rock ballasted, and are very largely equipped with tie plates. This rigid track construction has placed a greater duty upon the chilled-iron wheel, a condition which it is felt the manufacturers possibly have not realized, for little or no effort has been made to improve the quality of the wheels to meet these severe conditions.

The cast-iron wheel is about the only part of railway equipment which is not purchased to a chemical specification; yet it is the most important part of such equipment. The failure or breakage of one wheel in a train almost invariably results in derailment. Such chemical specifications as have been recommended are not generally acceptable both to the manufacturer and the consumer. It is generally conceded that unless an improvement is made in the quality of cast-iron wheels, the railway lines will be forced to give careful consideration to the use of steel wheels, with the hope that fewer failures will result in service. From a study of the service condition of cast-iron wheels, we are of the opinion that this wheel can be greatly improved, and that it will be found to be satisfactory under nearly all equipment. It has been claimed that the ordinary wheel on certain lines is satisfactory. This may be true where such lines do not have any lengthy and heavy grades, but where these grades do exist failures from cast-iron wheels are constantly resulting; and as all class of equipment is handled over these lines, it is therefore necessary that the wheels on all lines be made of the best possible composition.

TABLE II.—WHEELS FAILED IN SERVICE.

(All values in per cent.)

Mark.	Cast.	Total Carbon.	Graphitic Carbon.	Combined Carbon.	Phosphorus.	Sulfur.	Manganese.	Silicon.
1........	8-27-17	3.24	2.24	1.01	0.420	0.176	0.57	0.70
2........	....	3.36	2.13	1.23	0.430	0.191	0.41	0.82
3........	....	3.35	2.46	0.89	0.440	0.200	0.65	1.06
4........	4-15-18	3.37	1.87	1.50	0.384	0.182	0.39	0.75
5........	5-28-13	3.34	2.19	1.14	0.388	0.199	0.52	0.75
6........	3-28-18	3.34	2.10	1.24	0.386	0.146	0.36	0.76
7........	6-28-20	3.22	1.91	1.31	0.354	0.193	0.52	0.80
8........	8-21-19	3.20	1.99	1.21	0.381	0.261	0.67	0.88
9........	3-14-18	3.19	2.24	0.95	0.364	0.171	0.50	0.84
10........	3- 9-20	3.34	2.15	1.19	0.428	0.185	0.52	0.69
11........	10-13-17	3.19	2.16	1.03	0.408	0.138	0.38	0.70
12........	9- 3-19	3.33	2.24	1.08	0.370	0.197	0.60	0.76
13........	12-30-18	3.32	2.34	0.98	0.420	0.175	0.79	0.73
14........	....	3.12	2.14	0.98	0.420	0.219	0.72	0.93
15........	2-17-15	3.32	2.20	1.12	0.400	0.190	0.43	0.68

During the year 1920, forty-two failures occurred from broken wheels on the lines of the Lackawanna Railroad, and with very few exceptions these were on foreign cars. For 1921, fourteen failures have occurred which caused derailment.

Four wheels were selected from a number of wheels which had been worn out and marked A, B, C, and D. Table I shows the date each wheel was cast, and gives the composition. It will be noted that in most cases these wheels meet the requirements of the specifications recommended later, although no effort apparently was made to make the wheels to any specification. The table shows the fact that the composition as to phosphorus and sulfur, and especially silicon, is fairly satisfactory. It should also be pointed out that the wheel with the lowest sulfur and lowest phosphorus apparently gave the best service. The higher silicon wheels in all cases showed more wear than lower silicon wheels. On the other hand it is believed that the combined carbon content, which in one case is as high as 0.99 per cent, is outside the limit for a cast-iron wheel which would give the best service.

TABLE III.—CHEMICAL ANALYSES OF WHEELS FROM THREE FOUNDRIES.

(All values in per cent.)

Foundry.	Total Carbon.	Graphitic Carbon.	Combined Carbon.	Phosphorus.	Sulfur.	Manganese.	Silicon.
B	3.37	2.58	0.79	0.320	0.157	0.57	0.70
	3.49	2.70	0.79	0.350	0.143	0.53	0.67
	3.30	2.47	0.83	0.320	0.143	0.61	0.69
	3.19	2.56	0.63	0.340	0.157	0.59	0.73
	3.45	2.68	0.77	0.370	0.164	0.54	0.77
	3.35	2.78	0.57	0.350	0.144	0.52	0.72
	3.34	2.83	0.51	0.340	0.142	0.50	0.77
	3.37	2.86	0.51	0.360	0.158	0.48	0.74
A	3.40	2.63	0.77	0.290	0.158	0.54	0.63
	3.16	2.55	0.61	0.350	0.153	0.68	0.64
	3.26	2.53	0.73	0.300	0.142	0.57	0.74
	3.55	2.94	0.61	0.290	0.130	0.59	0.76
	3.37	2.84	0.53	0.270	0.141	0.56	0.69
	3.42	2.94	0.48	0.300	0.148	0.54	0.75
	3.31	2.69	0.62	0.296	0.144	0.52	0.76
N	3.50	2.65	0.85	0.320	0.148	0.52	0.65
	3.47	2.57	0.90	0.330	0.132	0.49	0.71
	3.17	2.41	0.76	0.280	0.141	0.60	0.63
	3.15	2.36	0.79	0.330	0.132	0.59	0.68
	3.29	2.49	0.80	0.320	0.134	0.61	0.66
	3.31	2.56	0.75	0.320	0.130	0.55	0.64
	3.21	2.51	0.70	0.330	0.134	0.58	0.72
	3.29	2.56	0.73	0.292	0.142	0.52	0.70
	3.35	2.60	0.75	0.292	0.125	0.58	0.75
	3.27	2.46	0.81	0.296	0.137	0.60	0.71
	3.29	2.50	0.79	0.286	0.140	0.52	0.72
	3.32	2.55	0.77	0.300	0.126	0.57	0.74
	3.26	2.75	0.51	0.304	0.135	0.53	0.67

Table II shows a list of wheels which failed in service and in each case caused a serious derailment. Note here the high combined carbon, high phosphorus and uniformly high sulfur, in some cases low manganese, and in many cases high silicon. Wheels of this composition should not, under any circumstance, be placed in service. It will be noted that some of these wheels gave very little service, and we feel quite safe in saying that the wheels described in this table were shipped without the knowledge of the manufacturers as to their chemical composition.

Table III shows our analyses on a number of wheels made on different dates by three different wheel foundries, the majority being cast in 1920. Under foundry "B," which was asked to furnish wheels with not over 0.35 per cent phosphorus, it will be noted there is considerable high phosphorus. This we might say was their first attempt to make wheels to a chemical specification. The same request was made of foundry "A," and in this case all wheels conform to the specification as to phosphorus. In foundry "N" effort was then made to have the wheels contain not over 0.32 per cent phosphorus. It will be noted that in every case the wheels conform very closely to the specification, and it is felt that no undue hardship will be imposed upon the wheel makers to have phosphorus not over 0.32 per cent and that a better and safer wheel will in every case be produced.

TABLE IV.—REPORT OF WORN AND DEFECTIVE WHEELS INSPECTED AT KEYSER VALLEY SHOPS

Cause of Removal.	60,000-lb. Capacity.			80,000-lb. Capacity.			100,000-lb. Capacity.		
	Number of Wheels.	Average Age.		Number of Wheels.	Average Age.		Number of Wheels.	Average Age.	
		Yrs.	Mos.		Yrs.	Mos.		Yrs.	Mos.
Seamed rim	41	11	..	32	7	3	6	6	3
Worn tread	40	7	10	25	6	11	2	5	2
Shelled out	18	8	7	29	6	9	6	4	10
Cracked plate	98	5	6	109	4	6	40	2	11
Cracked hub	5	2	7	2	9	1	1	3	7
Brake burns	68	4	9	41	4	10	14	3	5
Slid flat	124	4	11	44	3	5	14	1	10
Worn flange	120	9	..	98	7	5	22	6	11
Worn through chill	5	10	2	5	5	11	2	8	4
Chipped rim	32	8	11	38	7	3	10	7	7
Chipped flange	6	5	..	5	8	1	1	2	6
Seamed flange	5	6	8	4	7	3	1	2	6
Hollow rim	1	11	2	...	..	..	...	..	..
Seamed tread	3	6	10	2	4	9	5	3	11
Averages and totals	566	6	11	434	5	11	124	4	4

It is not contended that a chemical requirement will at once eliminate all wheel failures, for it is possible that an occasional wheel will fail in service from inferior composition due possibly to some oversight on the part of a workman in the foundry.

In order to show the necessity for chemical requirements in a specification, we call attention to an analysis of 1124 wheels from 28 different foundries that were being removed in our shop in the ordinary routine of operation. No selection whatever was made; the wheels were taken just as they came into the shop to be removed for the various causes cited in Table IV.

The average life of these 1124 wheels was 6 years and 3 months. The total percentage of cracked plates in this lot is approximately

20 per cent. Taking this as an average, the total number of wheels removed for cracked plates during a period of twelve months on the Lackawanna Railroad would be approximately 8000.

In our judgment, the cracking of plates is due very largely to inferior chemical composition. Seamy rims and seamy treads are as a rule due to foundry practice, and are usually the result of metal being poured at too low a temperature. It is hardly necessary to call the attention of the manufacturer to the necessity of immediate improvement in both manufacture and composition of cast-iron wheels.

It is recommended that the question of drop test and thermal test be carefully investigated. We believe these tests should be made as severe as possible, so that none but good wheels may be shipped.

The Association of Manufacturers of Chilled Car Wheels, representing a large number of manufacturers throughout the United States and Canada, have given assurance that they are anxious to lend all possible assistance in the production of a first-class wheel. We are therefore recommending the following specification, covering all weights of chilled iron wheels:

SPECIFICATION "A".

Total carbon,	per cent	3.00 to 3.65
Combined carbon,	"	Not over 0.85
Manganese,	"	0.50 to 0.75
Phosphorus,	"	Not over 0.32
Sulfur,	"	" " 0.17
Silicon,	"	0.45 to 0.75

It is felt that the heavier wheels which are now being recommended will have a further tendency to reduce failures.

It is recommended that special consideration be given to a wheel which contains a small percentage of nickel and chromium, as indicated in specification "B." Wherever wheels of this composition have been placed in service, the results have been highly satisfactory; and the wheels should be especially suitable for the heavier equipment. The increased cost of these special wheels will run from seven to ten per cent.

SPECIFICATION "B".

Total carbon,	per cent	3.20 to 3.75
Combined carbon,	"	0.40 to 0.80
Manganese,	"	0.45 to 0.65
Phosphorus,	"	Not over 0.15
Sulfur,	"	" " 0.17
Silicon,	"	0.45 to 0.70
Chromium,	"	0.10 to 0.25
Nickel,	"	0.10 to 0.20

Every wheelmaker understands that while his metal may be of the proper composition, an inferior wheel can be produced due to faulty foundry practice, such as allowing wheels to be cold when pitting, or maintaining pits in improper condition. However, if the foundry practice is correct and the wheels are of the proper chemical composition, there is every reason to believe that a good, safe, cast-iron wheel can be produced. The drop and thermal tests, together with an examination of the fracture and depth of chill, usually reveal the method of foundry operation.

The majority of the failures of wheels previously cited occurred near the bottom of long, heavy grades, probably due to the elevated temperatures which the wheels attained. In nearly all cases failure occurred by rupture of the plate, and it is important, therefore, that the composition be controlled so that as much strength as possible may be obtained and the wheel enabled to withstand the elevated temperatures developed on all heavy grades.

With the increase in weight of the wheel, the heavier plates and thicker flanges, together with chemical composition requirements, there is good reason to believe that the cast-iron wheel will continue to serve the railways of the United States for many years to come.

DISCUSSION.

[The paper by Mr. Force was discussed jointly with the report of Committee A-3 on Cast Iron.[1] In the presentation of this report the chairman, Mr. Richard Moldenke, submitted, on behalf of the committee, proposed Tentative Specifications for Cast-Iron Car Wheels with certain revisions embodying chemical requirements which had been adopted at a meeting of the committee held during the annual meeting.[2] Mr. Moldenke moved that the specifications as thus revised be accepted for publication as tentative, and this motion was pending during the presentation of Mr. Force's paper and the discussion that follows.—ED.]

Mr. Doke

MR. G. E. DOKE.—I have read Mr. Force's paper with a great deal of interest and I am heartily in sympathy with the idea of obtaining a better cast-iron wheel for general service and also with the chemical limits he has quoted. These limits are similar to those contained in a tentative cast-iron wheel specification which we issued on the New York Central Lines several months ago.

The railroads of the country can only expect consistent, safe and satisfactory service from all cast-iron wheels when the desirability of a well-balanced and properly manufactured cast-iron wheel is appreciated by both manufacturer and purchaser. That a better wheel than the standard M.C.B. wheel is desired is evidenced by the fact that many railroads are to-day purchasing various kinds of special cast-iron wheels for use under their own heavy equipment, and purchasing standard M.C.B. or A.R.A. wheels for interchange repairs. It is evident that many purchase cast-iron wheels with utter disregard to test or composition of the wheels in question, and these wheels, passing from the owner's road, fail in service on some other road. I am convinced that the standard cast-iron wheel, if carefully made and balanced as to chemical composition, will give satisfactory service, the equal of many of the so-called special cast-iron wheels.

We have over 2,000,000 standard cast-iron wheels in service and to my knowledge none of them, purchased during the past two years, have failed or caused a wreck or derailment. I am of the opinion that this condition has been brought about by carefully

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[1] See p. 96.

[2] These revisions appear in the Addendum to the Report of Committee A-3, p. 98. The revised specifications appear on pp. 481–485.

Mr. Doke. checking wheels which have failed in the present required tests and also to the fact that we have eliminated the wheels where the chemical composition did not show proper balance. To illustrate the point in question, let me call your attention to certain thermal tests recently made:

TAPE	1	2	3
Chill at throat, in.	$1\frac{1}{16}$	$\frac{11}{16}$	$\frac{1}{2}$
Chill at tread, in.	$1\frac{1}{8}$	$\frac{3}{4}$	$\frac{9}{16}$
Total carbon, per cent. . .	3.29	3.46	3.45
Graphitic carbon, " . . .	2.27	2.20	2.52
Combined carbon, " . . .	1.02	1.26	0.93
Manganese, " . . .	0.54	0.66	0.66
Phosphorus, " . . .	0.38	0.38	0.36
Sulfur, " . . .	0.155	0.166	0.162
Silicon, " . . .	0.415	0.465	0.555
	Failed in 70 seconds	Failed in 100 seconds	Passed but rejected

The test on the tape No. 1 of a certain date cast failed in the thermal test in 70 seconds, combined carbon being 1.02 per cent. All tape No. 1 wheels were therefore rejected and a test wheel from the tape No. 2 wheels taken. This test failed in the thermal test in 100 seconds; combined carbon 1.26 per cent. All tape No. 2 wheels were thus rejected and a test taken from the tape No. 3 wheels of this same date. This wheel passed the requirements of the thermal test, although the combined carbon was shown to be 0.93 per cent. As the tape No. 3 wheels were still apparently unbalanced the entire lot was rejected. Such action is not supported under present existing specifications. Unquestionably difficulty would have been experienced had these wheels which passed the thermal test been accepted.

Another case illustrating the same point:

TAPE	1	2
Chill at throat, in.	$\frac{7}{8}$	. . . .
Chill at tread, in.	1	. . . .
Total carbon, per cent.	3.63	3.67
Graphitic carbon, "	2.29	2.52
Combined carbon, "	1.34	1.15
Manganese, "	0.33	0.38
Phosphorus, "	0.36	0.35
Sulfur, "	0.162	0.153
Silicon, "	0.49	0.64
	Failed in 105 seconds	Passed but rejected

Tape No. 1 failed in thermal test in 105 seconds; combined carbon 1.34 per cent. Tape No. 2 of the same date cast passed the

Mr. Doke.

thermal test, but the unbalanced condition is plainly shown by the high combined carbon, this being 1.15 per cent.

The requirement that the manganese content shall be at least three times the sulfur content is nothing new. This has, to my knowledge, been specified in B. and O. specifications for some years. The fallacy of considering low sulfur content as the only requisite for obtaining properly balanced and safe cast-iron wheels has also been exploded. Without presenting a mass of data, I will give a summary of the cast-iron wheels which have failed on our line during the past two years. These wheels were all foreign cast-iron wheels and have caused wrecks and derailments, the total number being 23:

FAILED CAST-IRON WHEELS WHICH CAUSED WRECKS OR DERAILMENTS DURING PAST TWO YEARS; TOTAL NUMBER, 23.

Number over 0.85 in combined carbon		16
(Highest combined carbon, 1.55–1.38–1.34–1.32–1.30)		
Number under 0.50 combined carbon		3
(Lowest combined carbon, 0.03)		
High in phosphorus (over 0.35)		15
(0.45, 0.44, 0.41, 0.40)		
Highest sulfur	0.231	
Lowest sulfur	0.12	
Average sulfur (All 23)	0.175	

I give also a condensed statement of failed cast-iron wheels found under cars by our car inspectors, these wheels being badly cracked or broken, total number 39:

FAILED CAST-IRON WHEELS FOUND UNDER CARS BY CAR INSPECTORS; TOTAL NUMBER, 39.

Number over 0.85 in combined carbon		26
(Highest combined carbon, 1.44 and 1.31)		
Number under 0.50 in combined carbon		5
(Lowest combined carbon, 0.07)		
Extremely high in manganese (0.92) and silicon (0.83)		1
High manganese (0.75) in comparison with sulfur content		1
and high phosphorus (0.49, 0.42, 0.39, 0.37)		4
Satisfactory in so far as chemical is concerned		2
Highest sulfur	0.265	
Lowest sulfur	0.110	
Average sulfur	0.163	

It is apparent that if the wheels are unbalanced as to chemical composition, this condition is nearly always indicated by high combined carbon. This does not always hold true if the wheels are injured by bad shop practice, although in many cases this undesirable condition is also indicated by the high combined carbon. The majority

Mr. Doke.

of the cast-iron wheel manufacturers fully realize the seriousness of the situation; they are cooperating with us in every way, and as I have stated above satisfactory results have been obtained during the past two years in so far as the New York Central Railroad is concerned.

Mr. Moldenke.

MR. RICHARD MOLDENKE (*Chairman of Committee A-3*).—I had come prepared to oppose the injection of chemical requirements into specifications based upon physical tests of cast-iron products, as I believe this to be unwise if not actually unfair. However, as the manufacturers of car wheels on the committee have acquiesced in the matter, theirs will be the burden. I do believe that it is possible to improve the cast-iron car wheel. I am glad to repeat the remark in Mr. Force's paper relative to the addition of nickel and chromium, particularly if this comes in the pig iron used, for reasons of uniform distribution and economy.

However, I think that instead of loading specifications with items difficult of application in daily routine, it would be better to aim for better wheels by using better processes, and the electric furnace offers the very best opportunity in that direction. With perfect results in the way of super-heat, deoxidation and desulfurization, many of the present influences making for dangerous wheels will be eliminated, and a uniform and excellent run of castings should eventuate. Almost one hundred per cent of scrap wheels can be used, offsetting the higher melting cost, and the composition of the wheel will be under far better control than is now the case. The manufacturers of car wheels will do well to look into the situation, and they should be helped in this direction by the railroads, so that when the time comes for the definite adoption of the tentative specifications the subject will be fully understood.

The President.

THE PRESIDENT (MR. GEORGE S. WEBSTER).—A number of the manufacturers of car wheels have been invited here to-night to discuss these specifications, and we shall be glad to hear from them. I invite Mr. George W. Lyndon, President of the Association of Manufacturers of Chilled Car Wheels, to address us.

Mr. Lyndon.

MR. GEORGE W. LYNDON.—I was invited by your Secretary to come here and discuss the question of failures in cast-iron wheels as given by Mr. Force. I will not discuss the question as far as technicalities are concerned, but I think a brief statement from me as to the attitude of our Association towards the recommendations of Mr. Force might be appropriate. In the first place, our Association represents twenty-five car wheel manufacturers throughout the United States and Canada, having a capacity of 20,000 car wheels per day. We have with us to-night three or four manufacturers **Mr. Lyndon.** who are located in Eastern territory and who will speak to you about the recommendations of Mr. Force later. The province of our Association is, and has been ever since we have been organized, for the purpose of improving the chilled-iron car wheel, and it must follow that we are interested in any proposition that will help to solve the problem with which the chilled-iron car wheels manufacturers are confronted. For the purpose of improving the quality of the wheel, we have worked with associations throughout the United States and also through State Universities. We have made a wonderful improvement in the chilled-iron car wheel, and to-day have four standards, something we never had before, that are absolutely the same in contour:

650-lb. wheel for 30-ton car,
700-lb. wheel for 40-ton car,
750-lb. wheel for 50-ton car,
850-lb. wheel for 70-ton car.

As far as standards are concerned, we can safely say that we have a standard that we are proud of and we can make good wheels from these standards. As far as chemical specifications are concerned, our Association as a whole believes in chemical specifications. I cannot stand here to-night and tell you gentlemen that we approve of the recommendations of Mr. Force, because we have only four car wheel companies represented here and, while these four companies may believe in the recommendations made by Mr. Force, we have twenty-one companies who are not represented, some of whom might recognize the chemical specifications evolved by Mr. Force while others might object to them. The question of the manufacture of the car wheel is a variable one, due to location and materials. We can, in some territories, get materials which will be in keeping with the requirements of the specifications as voiced by Mr. Force; in fact, in any part of the country we can get materials so that we can recognize the specifications and the limitations that are placed. But, it is a hardship for a plant located on the Pacific Coast to be forced to buy material that will meet these specifications when the material is not adjacent to their territory; it is a hardship for the Southern people to secure material that will meet these specifications and, in procuring special material, it will necessarily follow that the price of the car wheels might have to be increased.

We are heart and soul with any movement that will improve the chilled-iron car wheel, and I want to tell Mr. Force and all of the gentlemen who have contributed to its improvement (as Mr. Doke,

Mr. Lyndon. for instance) that we will cooperate with them in every movement that will improve the quality of the wheel. We know we have not a perfect wheel, but we do believe we have a wheel that has stood the burden and the test of service for seventy years, and nothing has made serious inroads on it. We can make it better, we want to make it better and we have tried in every way to improve its quality. At the present time we have instituted a physical laboratory and, as Mr. Moldenke suggested, we have in connection therewith an electric furnace. It will be our purpose to remove from some of the irons what we suppose to be injurious qualities, and see if by removing the injurious elements in the wheel we can improve its quality. We can go at this work scientifically, and it will take us some time to evolve a proposition that will be satisfactory to us and also satisfactory to the users; nevertheless I mention this to show you that we are in the business for the purpose of improving the wheel, and our by-laws specifically state that it is for that purpose we are organized and for no other.

Regarding Mr. Force's specifications and those submitted by the committee for action of the Society, we cannot now accept them as an Association. After the specifications are passed upon by the American Society for Testing Materials, we will take with us a copy of your recommendations and submit them at our quarterly meeting. We will submit these specifications to our members and, if they are satisfactory, we will accept them; if not, the Society will be so advised.

In closing, I want to express my appreciation to Mr. Force for the paper he has read. It is an excellent paper; it has been prepared with a great deal of difficulty, and I want to say that our Association believes that it should commend any man who will take the initiative in formulating a scheme to improve an article of commerce upon which the nation is dependent. I thank you.

Mr. Vial. MR. F. K. VIAL.—I will take but a few minutes of your time to discuss this question which is so important to the chilled-iron wheel industry. I simply wish to state that there is no subject in which the wheel manufacturers take a more vital interest than in the improvement of their product, and I am sure we are indebted to Mr. Force for the investigation which he has made and the suggestions which he has brought before us in so far as they will improve the quality of our product.

The chilled-iron wheel is essentially a carbon proposition. Carbon exists in chilled iron in two forms: first, combined with iron making a hard, white structure; second, a portion of the carbon exists as graphite. The A.R.A. specification calls for the chilled iron bordering the flange and tread to be not less than $\frac{1}{2}$ nor more than 1 in. in depth. In other words in this zone all the carbon must be combined—no graphite is permissible. This delicate reaction is controlled by silicon. Whether or not the specification for chill has been fully complied with is determined by breaking representative wheels. The depth of chill is visible at the fracture, and its depth is a mere matter of observation. No chemical analysis can determine the depth of chill. Therefore, a specification for silicon becomes superfluous. **Mr. Vial.**

The body of the wheel must possess a maximum strength and be sufficiently soft for easy machining. This can only occur when the combined carbon is below 1 per cent, the balance of the carbon being interspersed as graphite. The paper of the evening suggests the maximum for combined carbon to be 0.85 per cent. This is considered too low by most manufacturers for the best results. We all strive to bring the combined carbon in the average product to this figure, but individual wheels should not be rejected unless the combined carbon exceeds 1 per cent. The regulation of combined carbon in the plate of the wheel and the depth of chill at the tread are controlled by the skill of the manufacturer, and since they are the results which must be secured it is entirely proper to fix in the specification the relation between combined carbon and graphite in the various parts of the wheel. When this regulation is correct we have a perfect wheel, always providing that the foundry work has been properly performed. The chemical elements as silicon, manganese, sulfur and phosphorus must be in the proper relationship to obtain the proper chill at the tread and absence of chill at the plate. When the relation between the carbons is correct the relation between the other elements is correct. It, therefore, becomes unnecessary to state the limits of the chemical elements. We must always depend upon the physical tests to determine whether the wheel has been properly made. The item of heat treatment is of far more importance than chemical analysis, assuming always that the chemical balance has been such as to produce a proper relation between carbons for the different parts of the wheel. There are two elements, namely, phosphorus and sulfur, which are not directly concerned in the carbon relationship. It is perhaps a question how far we should limit these two items when their presence has no definite effect on physical tests; in fact their presence often indicates an increased strength. The Griffin Wheel Co., for example, place their specification for phosphorus below 0.35 per cent. This is because the raw materials in our vicinity permit such a specification. It does not at all follow

Mr. Vial. that this specification should be made universal, for this would rule out Southern irons from consideration in the car wheel industry. We are too well acquainted with good qualities of Southern charcoal irons to suggest their elimination. If I were to write a chemical specification, I would emphasize the essentials and be sure that the non-essentials should produce no limitation to the commercial production of wheels by limiting raw materials and destroying the skill of the manufacturer. It is sufficient to specify that the average combined carbon in any lot of wheels should be below 0.90 per cent or 0.85 per cent; that individual wheels would be rejected if above 1 per cent; that the relation of manganese to sulfur should be at least 3 to 1. All other limitations as far as chemical analysis is concerned are superfluous. It is very noticeable in the instances cited by Messrs. Force and Doke that the analysis secured from the wheel failures indicate a disregard for the limitation of combined carbon because the manganese-sulfur ratio was disregarded. There is no case where the chemical balance was correct and combined carbon below a reasonable maximum where failure could be attributed to phosphorus; in fact I fail to find any relation between the failed wheels and phosphorus content. The specification which Mr. Force suggests is not inconsistent with good wheels, but there are large quantities of good wheels which do not fall within the limits suggested. It will be a great handicap to the chilled-iron wheel industry to restrict the chemical specification to such an extent as to eliminate raw materials, such as pig iron in the South and old wheels in the West, unless it can be clearly shown that by so doing a perceptible improvement can be made in the general character of chilled-iron wheels. It is unreasonable to ask the railroads for an increased price on account of a rigid chemical specification when a corresponding benefit cannot be shown.

Mr. McClumpha. MR. H. E. MCCLUMPHA.—I have nothing to add to what my predecessors have said. I have made wheels for eighteen years. I heartily recommend this tentative specification, and the National Car Wheel Co. stands ready to make wheels within those limits.

Mr. Courtney. MR. R. J. COURTNEY.—I cannot add anything to what has been said in regard to the technical manufacture of a car wheel. The New York Car Wheel Co. is making wheels to those specifications at present and will continue to do so. I do not think any better wheel can be made by changing those specifications, so we will continue to make them as we have been making them heretofore.

Mr. Brown MR. H. C. BROWN.—Gentlemen, the Brown Car Wheel Co. has been making wheels to the specifications of Mr. Force for a good many years, and we heartily approve of them. We feel that the higher the phosphorus the poorer the wheel. We feel that a phosphorus of 0.32 per cent, which we are making now, is about as good as we can do. **Mr. Brown.**

MR. A. C. CURRAN.—I can but repeat what has already been said by previous speakers. The Buffalo Car Wheel Foundry Co. is quite in line with the chemical specification as suggested by Mr. Force and is ready to make wheels conforming to it. We feel very strongly the importance of a well-balanced chemical composition and believe this to be a good one for wheels. **Mr. Curran.**

MR. MOLDENKE.—In connection with the demands on phosphorus in Mr. Force's proposal, those who have so far discussed the situation are from sections of the country well supplied with low-phosphorus metal. In common fairness, I would like to hear from the South, where high phosphorus is the rule and they also make good car wheels. **Mr. Moldenke.**

THE PRESIDENT.—Is any one present representing the Southern car wheel companies? Apparently there is no one. Is there any further discussion? **The President.**

MR. ROBERT JOB.—Mr. Force's interesting paper emphasizes the important relation which exists between the chemical composition of a cast-iron wheel and its service value. Different investigators have submitted evidence in this connection from time to time, Dr. Dudley among others, but for one reason or another chemical composition has not been included in the M.C.B. or A.R.A. specifications or in most of the other specifications with which we are familiar. It occurs to me that some work which was undertaken upon the Lehigh Valley Railroad in 1909 may be of interest to the Society. **Mr. Job.**

Careful study had been made prior to that time of failures of cast-iron wheels, and upon summarizing the results we found several outstanding features, as follows:

First, combined carbon in the large majority of cases exceeded 0.90 per cent;

Second, phosphorus almost always was above 0.30 per cent; and

Third, sulphur generally exceeded 0.15 per cent.

Other elements in many of the failed wheels were found defective, particularly manganese and silicon, but those noted above appeared to be specially characteristic.

As a result of this work chemical requirements were at that time adopted as our standard practice, and the cast-iron wheels which have been ordered by the Lehigh Valley for use under its freight equipment since that time have been under the following requirements:

Mr. Job.

Combined carbon, per cent		0.50 – 0.75
Phosphorus,	"	not over 0.30
Sulfur,	"	" " 0.14
Manganese	"	0.60 – 0.70

These limits in the light of subsequent experience might be changed slightly, and we should be satisfied to place the range in combined carbon at from 0.60 per cent to 0.85 per cent as has recently been proposed by the New York Central; but we consider 0.85 per cent as the extreme maximum which should not be exceeded. As to phosphorus, we prefer to retain the maximum at 0.30 per cent, with sulfur not exceeding 0.16 per cent, and manganese at 0.50 per cent to 0.70 per cent. With metal of this composition and with proper precautions as to foundry practice, we have found it practicable to make a decided increase in the number of blows under the drop, as for instance:

700-lb. wheel.......30 blows of 200-lb. weight falling 10 ft.;
750-lb. " ....30 " " 200-lb. " " 12 ft.

Instead of increasing the number of blows it is obvious that the height of drop might be increased. This would lessen the time required for making the tests.

As to the drop test, it is well recognized that the requirements of the usual specifications are far below the capacity of the wheels, assuming that the quality is normal, and we are glad to know that it is the plan of the Sub-Committee on Car Wheels to make a study during the ensuing year of the relation existing between physical tests and chemical composition of wheels. It is probable that as a result of this work, recommendations can be made which will aid in placing the physical testing of wheels upon a much more satisfactory basis than is the case at the present time.

In our shipments upon the Lehigh Valley we have held to the composition mentioned above by means of regular check tests. The improvement in service has been marked, and as a result of the tougher metal we have found it possible to get stronger, safer, and more serviceable wheels well adapted to meet the conditions of present-day requirements.

Unfortunately action of this kind by any one road does not give full protection even upon its own lines, for replacements may be made when the cars are upon other roads and such wheels may be of radically defective composition and quality, and the same condition is liable to be present in foreign wheels. We hope to find, therefore, that the importance of the revision of its present specifications for cast-iron wheels will be felt by the American Railway Association, and that among other matters limits as to composition may be fixed which in conjunction with suitable physical tests will offer reasonable assurance of obtaining good service, and of rejecting the grades which have been causing expensive derailments and repairs. **Mr. Job.**

Mr. Ripley. MR. C. T. RIPLEY.—The Atchison, Topeka and Santa Fé Railroad, with which I am connected, operates over many mountain grades and the question of cracked-plate wheels has been given serious consideration. The intensive study in this connection started about ten years ago. At first we were of the opinion that the chemical content was the governing factor. The more we went into the question the more we realized that there were other factors of as great, if not greater, importance.

Two important factors were encountered. We broke up about a thousand wheels with cracked plates and found that practically all had dirt inclusions at the point of breakage; and investigations at the foundries indicated that this inclusion was the result of the shape of the plates being used. The manufacturers took hold of this question and developed what is known as the arch-plate wheel, which I think should be mentioned in any such discussion as this. The arch-plate wheel has now been in service a number of years. The 700-lb. wheel which took the place of the 675-lb. one was the first arch-plate wheel used on our road. This change cut the plate failures of this weight wheel to approximately one-tenth of what they were with the old style plates. The figures given in Mr. Force's paper do not state whether the wheels were the new arch-plate type adopted by the American Railway Association. I think, to make the figures more comparable, this information should be included.

The other factor was the service. By this I mean the way the trains were handled on the mountain grades. It is possible to destroy the very best of wheels by improper brake applications, by not using proper cooling periods, by running overspeed, etc. Then again we found that under our refrigerator cars we were using too light a wheel, a wheel that would not stand the service; the stress was simply too great for the metal, whether the phosphorus or sulfur were high or not. The American Railway Association Wheel Committee worked along these lines and recommended the change to arch-plate type of the other two classes of wheels, that is, the old 625-lb. wheel and the old 725-lb. wheel. They took the new design, recommended by the wheel manufacturers' association, and these wheels are now being put into service on most of the roads. Unfortunately some of the roads are still using some rather light wheels. If the proper weights of wheels as recommended by the Association, that is, the arch-plate type, were used

Mr. Ripley. and the roads had their brake handling on a proper basis on mountain grades, the number of cracked-plate wheels would show a very decided decrease. I know it was possible on one road and I have been told on other roads that the same results are being secured. To have 22 per cent of all wheel failures due to cracked plates is abnormal. It shows there is something wrong; either poor wheels, or they are not being handled right.

I do not mean to deprecate the chemical specification. We personally would be very glad to have it if it is a commercial possibility. Undoubtedly these gentlemen have made an investigation showing it is an advantage to hold down phosphorus and sulfur; but still I think the other two factors I have mentioned should also be given consideration and that you are all going to get better service out of cast-iron wheels due to the adoption of the new heavy arch-plate types.

Mr. Waterhouse. MR. G. B. WATERHOUSE.—I am not a cast-iron wheel man, although I have had more or less experience with cast iron, but looking at the proposed specifications from the steel standpoint, it seems to me that they will tie the cast-iron manufacturer down too closely. You are limiting them on combined carbon and very closely on manganese, on phosphorus and on sulfur, and in addition, you are limiting them on silicon, which is the one thing by which they can control their combined carbon. Now Mr. Job's specification does not mention silicon, because undoubtedly he realized that you must leave to the foundry man something to work with. I am not, as I say, a cast iron man and I am not on this committee, but it seems to me that we should give the manufacturer a chance to have something to work with to meet the other requirements of the specifications.

Mr. Young. MR. C. D. YOUNG.—I am in the peculiar position of being with a road (the Pennsylvania System) that is both a manufacturer and a buyer of wheels. If I understand this motion correctly, it is to include a complete chemistry with the specifications. I should like to ask what was the vote of the committee on the including of this specification requirement at its committee meeting? I ask that question as I have just come into the meeting and I am not informed as to our representative's view on this situation, and I feel that it is such an important and such a radical step to include in the cast-iron wheel specification both the physical requirements which have been the controlling requirements up to this time, and chemistry as well, that I would like to know what this will mean in the production of wheels with the raw materials from which the wheels are produced.

MR. DOKE.—Mr. G. B. Koch, Superintendent of the Pennsylvania Car Wheel Foundry and chairman of the Sub-Committee on Car Wheels of Committee A-3, wrote me during the past week that he possibly might not be able to be in attendance and requested that, in case he was absent, I serve as temporary chairman of the sub-committee. At the last meeting in Philadelphia, Mr. Koch stated that we would have a sub-committee meeting at Asbury Park, and it was understood we would consider and discuss chemical requirements in connection with the cast-iron wheel specification at this meeting. The members of the committee in attendance to-day were unanimous in passing on this subject as a tentative proposition. **Mr. Doke.**

For the benefit of Mr. Waterhouse, I desire to state that there is no question either in the north, south, east or west on the combined carbon limits as proposed. These are without question, I believe, acceptable to all of the cast-iron wheel manufacturers. The only question that I have heard raised has been with regard to the phosphorus and sulfur contents, thus accounting for the wide range in phosphorus which we have included in the chemical requirements of the suggested specification. We have placed the desired content for phosphorus at Mr. Job's requirement of not over 0.30 per cent and the maximum at 0.40 per cent to meet the requirements of those using southern pig irons, which we understand are higher in phosphorus. Possibly this will explain the question raised by Mr. Young.

[The proposed revised Tentative Specifications for Cast-Iron Car Wheels submitted by Committee A-3 on Cast Iron were then accepted for publication as tentative. They appear on page 481–485.—ED.]

MR. H. J. FORCE (*Author's closure by letter*).—The remarks of Mr. Doke are of special interest, as I know that he has given this matter very careful consideration, and has conducted very exhaustive tests and investigations; therefore, his discussion is of much importance,—representing as he does a company which has over two million cast-iron wheels in service. Certainly Mr. Doke has nothing at heart except the best interests of the New York Central System. **Mr. Force.**

The remarks of Mr. Robert Job are also of special interest, showing what has been done by certain manufacturers for a considerable time, and that satisfactory results are being obtained.

I can not impress too strongly the importance of very serious consideration being given to work such as has been done by Mr. Job; certainly investigations of this kind are what are desired by the A. R. A., so as to furnish them with definite information regarding cast-iron car wheels, with special reference to further improving their specifications.

Mr. Force. In reply to Mr. C. T. Ripley, I would say that the wheels in question were largely of the old type, although many wheels of the new arch plate type are included in the list.

In reply to remarks of Mr. Vial, I do not agree with Mr. Vial that a silicon content in a specification is superfluous. The silicon content with the other elements normal in a wheel of this kind should not run below 0.45 per cent, nor exceed 0.75 per cent. Ninety-five per cent of all broken wheels analyzed ran between 0.60 and 0.75 per cent silicon. A small percentage runs up to and above 1 per cent. A wheel with a high silicon content may show upon examination considerable chill, due to high sulfur and it is for this reason that the chemical requirements are placed in the specification. Over half the wheels which failed in service had combined carbon above 0.85 per cent, and a large number ran up to as high as 1.50 per cent.

Neither do I agree with Mr. Vial that a noticeable presence of phosphorus and sulfur indicates an increased strength in a cast-iron wheel. Over 90 per cent of the failures in cast-iron wheels show high sulfur and high phosphorus; evidently they do not possess sufficient strength.

I note that Mr. Vial is of the opinion that the specification as suggested is not inconsistent with good wheels. I think it is a well-known fact that not every piece of material which is of an unbalanced composition chemically always fails in service, but in the failure of a few the results in dollars and cents is often considerable, together with the loss of human life.

Mr. McClumpha of the National Car Wheel Co., Mr. Courtney of the New York Car Wheel Co., Mr. Brown of the Brown Car Wheel Co. and Mr. Curran of the Buffalo Car Wheel Co., who are engaged in the manufacture of car wheels (together with the American Car and Foundry Co., who were not represented at this meeting) have been making wheels to this specification for some time, and it is admitted that wheels so produced are apparently beyond question.

Mr. Vial refers to pig iron in the South and old wheels in the West. Quite a large number of the failed wheels shown in my report were either made by Southern or Southwestern foundries. More wheels fail from these two classes of foundries than all the rest put together, yet their production is considerably less. Wheels which were not bought to specifications, our records show, failed sometimes in three or four months. Mr. Doke and Mr. Job have both testified that wheels made to their specifications have, over a considerable period of time, been very satisfactory.

The steel wheel people have asked the railroads a price of ap-

Mr. Force.

proximately 300 per cent over the cost of cast-iron wheels, and many of the roads are of the opinion that this was a wise investment, more especially due to the fact that chilled iron wheels furnished in many cases were very unsatisfactory from a service standpoint, and yet the chemical composition for over a period of approximately 65 years has been left entirely in the hands of the manufacturers.

In reply to Mr. Moldenke, I would say that it is very evident from the facts submitted by both the manufacturers and the users of wheels that a chemical requirements is a commercial fact.

In reply to Mr. Waterhouse: As I have already stated, we have left practically everything, as far as chemical composition was concerned, to the manufacturer for the past 65 years. Wheels made to this specification stand a very much better drop and thermal test. The band in the thermal test has been increased on wheels up to 700 lb. to 1$\frac{3}{4}$ in. and above 700 lb. to 2 in. Wheels under this test show no signs of cracking at the end of two minutes and in many cases are found in perfect condition at the end of 5 and 10 minutes. Wheels under the drop test show no signs of developing any cracks with the use of a 200-lb. weight as now standard; nor do they develop any cracks with a 300-lb. weight until 5 to 8 blows have been struck. Wheels with high sulfur, high phosphorus and high combined carbon, as shown by Mr. Doke, fail very early in their thermal or drop test.

It is to be hoped that all users of cast-iron wheels, where used under heavier equipment, will give the question of chemical requirements and increase in thermal and drop tests very careful consideration, and that a large majority of the manufacturers will be glad to furnish wheels to a chemical composition.

METHODS OF CASTING MANGANESE-BRONZE TEST BARS AS A CHECK ON MELTS OF SMALL CASTINGS.

BY E. H. DIX, JR.

During the course of regular production of Manganese-Bronze castings for Air Service requirements, it became evident that a satisfactory method of casting a test bar separately as a check on melts of small castings would have to be developed. In consulting the literature on the subject and various Government and Technical Society Specifications, it was found that in general the method of separately casting a test bar is not well defined, and in several instances where a definite method was indicated, it did not seem to fit the requirements of the small experimental foundry at McCook Field. It was therefore necessary to experiment with several different types with a view to obtaining a method which would first of all give uniform results; second, would be easy to cut from the coupon using a band saw such as is found in the ordinary non-ferrous foundry, and which would also require as little machining as possible; third, one which would require only a small amount of metal, inasmuch as the melts poured in the foundry rarely exceeded 130 lb.; and fourth, it was desired to obtain a method which would give results as nearly as possible comparable with the average physical properties obtained in most sand castings.

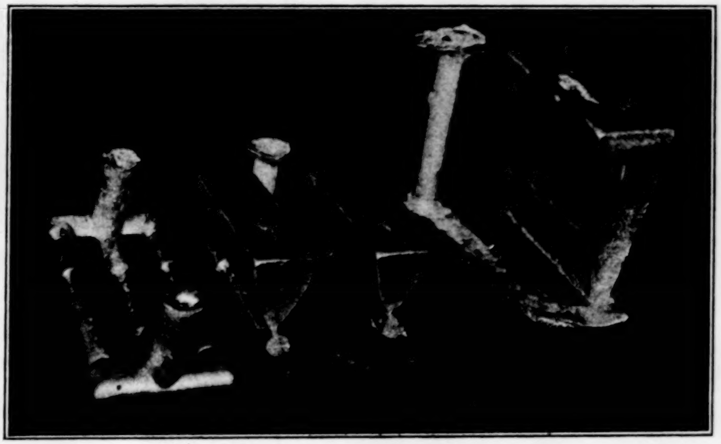
METHODS OF CASTING TEST BARS.

Fig. 1 is a photograph of the several methods which have been experimented with, all casting being done in green sand. These methods will be referred to according to their pattern numbers, as indicated. A full description of these follows.

Pattern No. TB-1 is a very common method for casting test bars of aluminum, red brass, and other metals of low shrinkage. The pouring head and riser are both $1\frac{1}{4}$ in. in diameter and a 3-in. cope is used. Usually the mold was tilted so that the pouring head would be 3 in. high and the riser about $2\frac{1}{4}$ in. high. The three specimens require 6 lb. of metal. These specimens were lettered *A*, *B*, and *C*, so that the center specimen was always marked *B*. These were tested as cast, the diameter over the gage length of 2 in. being approximately $\frac{1}{2}$ in. The enlarged ends were $\frac{3}{4}$ in. in diameter and 2 in. long. The bars were pulled in wedge grips.

Pattern No. TB-2A illustrates a wedge riser of a type often experimented with. This mold was also made with a 3-in. cope and the riser is 3 in. across the top and tapers down to a $\frac{1}{8}$-in. thick web, joining the test specimen. The metal was led to one end of the test bar through a long skim gate, the gate being cut entirely in the drag. A single specimen requires about 12 lb. of metal. The test specimen is $\frac{5}{8}$ in. in diameter over the gage length and $\frac{7}{8}$ in. in diameter over the enlarged ends, thus allowing $\frac{1}{8}$ in. on the diameter for machining to the standard $\frac{1}{2}$-in. diameter by 2-in. gage length specimen. This specimen was always machined with threaded ends and pulled in self-aligning adapters.

Pattern No. TB-2B is similar to No. TB-2A, except that the web joining the riser to the test bar is $\frac{1}{4}$ in. thick instead of $\frac{1}{8}$ in., and requires about the same amount of metal. In general, where both Nos. TB-2A and TB-2B were cast from the same melt, they were made up in the same mold with the gating as shown in the photograph. Where either was cast alone, the gating was similar with the exception that the branch gate for the other bar was omitted.



Pattern No. TB-1. Pattern No. TB-2B. Pattern No. TB-2A. Pattern No. TB-2S.

FIG. 1.—Methods of Casting Test Specimens.

Pattern No. TB-2S represents a method recommended by one large manufacturer of manganese bronze. The test bar is $\frac{7}{8}$ in. square and is located in the drag with a cope 7 in. high. The wedge riser is $3\frac{1}{2}$ in. across the top and tapers down to the full width of the bar ($\frac{7}{8}$ in.). It requires about 33 lb. of metal. The metal is led to the test bar through a long skim gate cut in the drag. The standard $\frac{1}{2}$-in. diameter by 2-in. gage length test specimen with threaded ends was machined from the square bar.

Test Bars Cut from Ingots.—The American Society for Testing Materials recommends in its specifications for manganese bronze ingot casting metal that the test bar be cut from one corner of an ingot near the bottom. Some results were also obtained by this method as a check on the other methods employed.

Test Bars from Castings.—In order to obtain a comparison between the separately cast test bars and test bars cut from castings, several castings have been cut up and tests made on specimens of varying sizes.

FOUNDRY PROCEDURE.

All melting was done in an Iler No. 40 oil-burning furnace, the ordinary type of plumbago crucible being used. Charcoal was used as a covering for the melts. No other flux was used. The temperature was measured by means of a Chromel-Alumel couple protected by a Chromon tube. The maximum furnace temperature was taken just before the pot was pulled, and again after stirring and skimming, and this temperature is denoted as the pouring temperature in Table II. It is common practice to pour manganese bronze at the temperature at which the zinc flare is noticeable only when the surface of the metal is disturbed. This corresponds to a temperature between 1700 and 1750° F.

TABLE I.—CHEMICAL COMPOSITION.

SERIES No.	Melt No.		Copper.	Zinc.	Iron.	Tin.	Aluminum.	Manganese.	Total Hardeners.
1	540	As mixed..	56.6	40.0	1.25	0.50	1.00	0.61	3.36
		By analysis	56.82	40.0	1.14	0.59	0.99	0.47	3.18
	568	As mixed..	56.62	40.0	1.25	0.50	1.00	0.61	3.36
		By analysis	56.68	40.54	1.31	0.42	0.63	0.41	2.77
	597	As mixed..	56.77	40.00	1.25	0.35	1.00	0.61	3.21
		By analysis	56.67	40.15	1.41	0.53	0.74	0.50	3.18
	620	As mixed..	56.62	40.00	1.25	0.50	1.00	0.61	3.36
		By analysis	57.37	39.16	1.23	0.43	1.34	0.47	3.47
2	240	By analysis	58.05	38.64	1.38	0.49	1.37	0.06	3.31
	366	By analysis	56.98	39.90	1.18	0.88	0.97	0.09	3.12
3	271	By analysis	58.40	39.15	1.50	0.55	0.35	0.05	2.45
	431	By analysis	57.86	39.42	1.31	0.46	0.92	0.03	2.72
	433	By analysis	57.30	39.89	1.21	0.51	1.06	0.03	2.81
	435	By analysis	58.27	39.46	0.90	0.51	0.75	0.05	2.21

The results given in this paper are only a few of the many obtained but are representative of the lot.

Series No. 1 includes metal which was made up in the McCook Field foundry, using a hardener containing copper, iron, aluminum, and manganese, which was also prepared in this foundry. The general procedure in mixing these melts was to charge the crucible with the required amount of copper and hardener, with a liberal covering of charcoal. When the copper was melted the zinc was preheated and added piece by piece with thorough stirring. The tin was then added and the mass allowed to soak for about five or ten minutes. The pot was then pulled, thoroughly stirred, skimmed, and poured.

Series No. 2 consists of melts made up of ingot purchased from the outside. The general melting procedure was the same as in the case of Series No. 1, except that the metal was already mixed and no additions were made.

Series No. 3 consists of melts made up from another lot of ingot purchased from a different source. The melting procedure was the same as in Series No. 2.

TABLE II.—MELTING DATA.

Series.	Melt No.	Weight, lb.	Percentage of Scrap.	Time in Furnace, hrs.	Maximum Temperature, deg. Fahr.	Pouring Temperature, deg. Fahr.
1	540	48	none	$2\frac{1}{6}$	[b]	....
	568	124	none	2	1800	1750
	597	127	none	$2\frac{1}{4}$	1800	1760
2	620	129	none	2	1820	1720
	366	300	[a]	$1\frac{1}{2}$	1750	1700
3	431	100	none	$1\frac{1}{2}$	1750	1700
	433	100	50	$1\frac{1}{2}$	1750	1700
	435	100	50	$1\frac{1}{2}$	1750	1700

[a] This melt made up in three meltings of 100 lb. each, the first being all new metal and the other 50 per cent scrap from previous melts.

[b] Protecting tube burnt through but temperature judged by zinc flare to be 1700 to 1750° F. when pulled from furnace and it was poured immediately.

TABULATED RESULTS.

The results given in this paper are presented in three tables.

Table I gives the chemical analyses of all of the melts, and also the proportions of elements, as mixed, for the melts made up in the McCook Field foundry.

Table II gives the melting data for all of the melts.

Table III gives the results of physical tests. These are given in some detail in order that the degree of uniformity of the different methods of casting test bars may be fully shown.

DISCUSSION OF RESULTS.

A consideration of the different methods of casting test bars used in these experiments shows that the results for pattern No.

TABLE III.—PHYSICAL TESTS.

Melt No.	Pattern No.	Specimen No.	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation, per cent.	Location of Fracture.	Type of Fracture.	Brinell, 500 kg.	Scleroscope.	Specific Gravity.
SERIES 1.										
540	TB 2B	1	45 470	83 770	22.5	M.T.	....	156	24	8.24
		2	38 900	83 370	20.5	O. T.	....	156	24	....
		3	34 360	84 480	23.5	O. T.	....	159	24	....
		Average	39 580	83 980	22.2	....	....	157	24	....
568	TB 1	3A	....	80 280	11.5	M. T.	Jagged	163	30	8 64
	TB 1	3B	40 490	64 780	5.0	M. T.	Jagged	163	30	....
	TB 1	3C	42 710	78 910	12.0	M. T.	Jagged	163	30	....
	TB 1	Average	41 600	74 657	9.5	....	....	163	30	....
	TB 2A	1A	52 920	72 730	....	O. S. G.	Jagged	119	30	8.05
	TB 2B	1B	56 200	84 310	17.0	O. T.	Jagged	119	29.5	8.15
	TB 2S	2	53 790	93 110	21.5	O. T.	Jagged	124	30.5	8.55
	Ingot	....	60 930	85 490	20.5	M. T.	Jagged	119	28	8.28
597	TB 2B	2	53 990	83 630	21.5	M. T.	Jagged	130	27.5	8.10
	[a]	....	43 820	72 240	13.5	....	....	99.3	23.6	8.24
620	TB 2B	....	39 720	71 910	15.5	O. S. G.	Jagged	143	27	8.27
	[a]	....	43 531	69 451	12.23	....	....	99.3	23.6	8 24
SERIES 2.										
366	TB 1	1A	38 790	64 650	13	M. T.	....	48	17	....
	TB 1	1B	36 000	67 390	16	M. T.	....	80	18.4	....
	TB 1	1C	40 800	65 520	12	M. T.	....	100	21.9	....
	TB 1	Average	38 530	65 850	13.7	....	....	76	19.1	8.27
	TB 1	4A	33 420	65 750	13	O. T.	....	55	19.8	....
	TB 1	4B	41 570	65 530	15	M. T.	....	93	21.8	....
	TB 1	4C	39 770	68 680	16	M. T.	....	114	21.8	....
	TB 1	Average	38 250	66 660	14.7	....	....	87.3	21	8.34
	TB 2A	4	34 240	65 490	16.5	O. S. G.	Granular	....	....	....
	TB 2A	6	30 610	59 790	10.5	O. S. G.	Granular	....	....	....
	TB 2A	9	34 330	67 060	17.5	O. S. G.	Granular	....	....	....
	TB 2A	Average	33 060	64 110	14.8	....	Granular	....	....	....
	TB 2B	5	32 810	67 050	22.5	M. T.	Granular	....	....	....
	TB 2B	7	30 570	70 100	26.0	O. S. G.	Granular	....	....	....
	TB 2B	8	31 680	69 510	29.5	M. T.	Granular	....	....	....
	TB 2B	Average	31 690	68 890	26.0	....	Granular	....	....	....
	TB 2S	S1	31 320	69 770	30	M. T.	Granular	....	....	....
	TB 2S	S2	32 190	69 370	30.5	M. T.	Granular	....	....	....
	TB 2S	S3	31 030	69 800	29.5	M. T.	Granular	....	....	....
	TB 2S	Average	31 510	69 650	30.0	....	....	....	....	....
240	Ingot	....	50 930	76 900	22	M. T.	Square	130	28	8.19
SERIES 3.										
431	TB 1	1A	....	68 860	19.0	M. T.	Square	....	....	....
	TB 1	1B	....	67 020	17.5	M. T.	Diag.	....	....	....
	TB 1	1C	....	48 770	9.5	Flaw	....	....	....	.
	TB 1	Average	....	67 940	18.3	....	....	....	....	....
433	TB 1	1A	....	65 090	15	M. T.	Jagged	....	....	....
	TB 1	1B	....	69 410	20.5	M. T.	Jagged	....	....	....
	TB 1	1C	....	62 330	12	M. T.	Jagged	....	....	....
	TB 1	Average	....	65 610	15.8	....	....	....	....	....
435	TB 1	1A	....	41 680	6.5	M. T.	Jagged	....	....	....
	TB 1	1B	....	65 670	15.0	M. T.	Jagged	....	....	....
	TB 1	1C	....	68 310	19.5	M. T.	Jagged	....	....	....
	TB 1	Average	....	58 550	13.7	....	....	....	....	....
	TB 1[3]	2A	....	43 900	12.0	M. T.	Cupped	....	....	....
	TB 1[3]	2B	....	43 090	12.5	M. T.	Cupped	....	....	....
	TB 1[3]	2C	....	75 840	22.0	M. T.	Jagged	....	....	....
	TB 1[3]	Average	....	56 280	15.5	....	....	....	....	....
431	TB 2A	2A	....	66 490	23.5	M. T.	Diag.	....	....	....
433	TB 2A	2A	....	70 540	32.0	M. T.	Jagged	....	....	....
435	TB 2A	3A	....	71 050	36.5	M. T.	Diag.	....	....	....
	TB 2A	Average	....	69 360	30.7	....	....	....	....	....
431	TB 2B	2B	....	70 210	30.0	M. T.	Jagged	96	23.5	8.28
433	TB 2B	2B	....	71 150	37.5	M. T.	Jagged	100	24	8.30
435	TB 2B	3B	....	70 260	36.5	M. T.	Diag.	105	22.5	8.33
	TB 2B	Average	....	70 540	34.7	....	....	100	23.3	8.30
431	TB 2S	3	....	70 380	30.5	M. T.	Jagged	....	....	....
433	TB 2S	3	....	69 290	33.5	M. T.	Jagged	....	....	....
435	TB 2S	4	....	71 230	39.0	M. T.	Jagged	....	....	....
	TB 2S	Average	....	70 300	34.5	....	....	....	....	....
271	Ingot	....	44 820	71 820	33.5	M. T.	Jagged	109	24.5	8.21

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[a] Average of 15 small test bars cut from casting shown in Fig. 2, Pattern No. X19342, weight, 53 lb.

[1] M. T. = Middle Third; O. T. = Outside Third; O. S. G. = Outside Gage.

[2] Not included in the average.

[3] Skin turned off reducing diameter about 0.02 in.

TB-1 are always extremely low. This is particularly true of the elongation. The results are also erratic and unreliable. This agrees with the experience of many who have endeavored to use this method of casting test bars, which, although very satisfactory for aluminum and red brass, is not satisfactory for a metal of high shrinkage, such as manganese bronze.

Pattern No. TB-2A also gives low and erratic results. The reason for this is perfectly evident, in that the $\frac{1}{8}$-in. web is not sufficiently heavy and freezes, thus preventing proper feeding action from the riser.

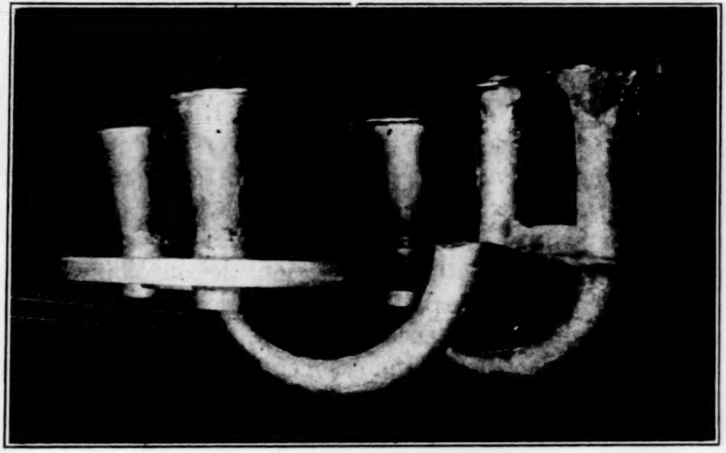

FIG. 2.—Casting (Pattern No. X19342) from which 15 small specimens were cut.

Pattern No. TB-2B has been found in all of the tests made to give uniform and reliable values. As an evidence of the uniformity, the three bars from melt No. 540 furnish a fair example.

Pattern No. TB-2S also gives uniform results, but ones which are believed to be fictitiously high, as, for example, 93,000 lb. per sq. in. obtained in melt No. 568.

The test specimens prepared from ingots in accordance with the A.S.T.M. specifications give results which are more nearly in accordance with those obtained from Pattern No. TB-2B than any other method.

The test specimens cut from the two castings shown in Fig. 2 give an average result somewhat lower than the figures obtained from pattern No. TB-2B. It is, of course, well known that the physical properties vary throughout different parts of the same casting, so that no one test bar can represent the physical properties in a casting. However, in choosing a method of casting test bars, it is desirable that the results obtained should be somewhat comparable to the average physical properties of the general run of castings.

Pattern No. TB-2S gives results which are so much higher than the average obtained in the castings that the designer would be seriously mislead if this method were adopted.

It is interesting to compare the metal in the three series on the basis of the two methods of casting TB-2B and TB-2S. Considering first the results from pattern No. TB-2S, melt No. 568 shows 93,000 lb. per sq. in., with an elongation of 21 per cent, whereas, the other two series would each show about 70,000 lb. per sq. in., with 30 to 35 per cent elongation. Thus, melt No. 568 would be judged far superior to the other two.

Considering the results from pattern No. TB-2B, melt No. 568 shows 84,000 lb. per sq. in., with 17 per cent elongation, whereas, Series No. 2 shows 69,000 lb. per sq. in., with 26 per cent elongation, and Series No. 3 shows 70,000 lb. per sq. in., with 35 per cent elongation. In other words, on this basis the metal in Series No. 3 is shown to be of equal quality with melt No. 568, the only difference being that one is "harder" than the other, and Series No. 2 is shown to be rather inferior. It would thus seem that, while some metals show good properties when fed in the exaggerated method of pattern No. TB-2S, yet when put in commercial castings where this amount of feeding is impossible, the results would not be as satisfactory.

Pattern No. TB-2S is an exaggerated case of methods being employed at present. A more reasonable method employed by one company is to cast a block about 4 in. square and of the desired test bar length, to the bottom of which are attached two or more square coupons for test specimens. The objection to this is that it is very difficult to make a straight cut 6 or 7 in. long through metal $\frac{7}{8}$ or 1 in. thick on the ordinary band saw, especially in a hard metal like manganese bronze. The riser in the case of pattern No. TB-2B is so proportioned that, although the web is only $\frac{1}{4}$ in. thick at the point of joining to the specimen, the riser begins to taper immediately, leaving just enough room for a saw cut, and the riser is further made sufficiently heavy so that it holds enough heat to prevent the web from freezing until the test bar is sufficiently well fed up to give uniform and dependable results. The test specimen may then be cut from the riser in the foundry and the fin ground off, so that in the machine shop it is only necessary to turn off $\frac{1}{8}$ in. of metal.

DISCUSSION.

Mr. Clamer.

Mr. G. H. Clamer.—The paper of Mr. Dix is one of considerable interest and value to those engaged in the casting of manganese bronze. Some of our members present will no doubt remember the very excellent paper on casting gun metal test pieces, presented before this Society by Mr. Webbert about seven years ago. Mr. Webbert in this paper described for the first time the method of casting a test piece by the use of the "fin gate." I made some experiments a year or two ago in connection with the use of gate such as described by Mr. Webbert for casting manganese bronze test pieces. I used gates not over $\frac{3}{16}$ in. in width. The test pieces so cast failed to show physical properties equivalent to those shown by test pieces cast by the regulation methods. Mr. Dix has made the discovery that by using a wider gate, namely $\frac{1}{4}$ in., instead of the $\frac{3}{16}$ in. gate used by me, test pieces are made showing physical properties comparing very favorably with previous best practice. Mr. Dix's discovery, although apparently quite simple, is nevertheless one of considerable value in that he has proved that manganese bronze test pieces may be cast by the Webbert method. By this method there results a great saving of metal in making the test pieces.

Mr. Comstock.

Mr. George F. Comstock.—This interesting paper is of value in bringing forward again the important fact that test bars cast from small melts of an alloy represent only the quality of the metal used for castings, and not necessarily the quality of the castings themselves. No test bar can possibly be an exact criterion of the physical properties of a casting because the gating and feeding of the latter are two very important factors that are not generally represented in the test bar in anything like the same way in which they affect the casting. Furthermore, different parts of a casting will have different properties depending on their positions relative to the gate and riser. Thus the use of a test bar should be definitely understood to be merely as a check on the quality of the metal entering into a casting, which is only one of several factors governing the actual properties of the casting.

The test bar obviously will not fulfill its function as a measure of the quality of the metal unless it is cast so as to obtain the best possible results, and Mr. Dix's paper brings out quite clearly the range of results that it is possible to get from different ways of making test bars. He is fortunate to be able to get satisfactory figures from a

Mr. Comstock. round bar fed through a $\frac{1}{4}$-in. fin such as is used for 88–10–2 zinc bronze. Most foundries have been unable to use such a bar with satisfaction for manganese bronze, and the safest method for general practice with this alloy would be to use the larger riser of Mr. Dix's pattern No. TB–2S, with its wide connection to the bar, or some similar method such as the keel-block about 4 in. square which he mentions. His own results indicate that such bars give the best representation of the metal used, while the bars that he recommends give only a more or less close approximation to this best result. The argument against the use of pattern No. TB–2S on the ground of exaggeration is based largely on the result from one bar of melt No. 568 in series No. 1, and thus seems hardly worthy of the prominence given to it by the author. It seems hardly correct to speak of "fictitiously high" results in this connection, for, as noted above, the proper function of a test bar is to show the best results obtainable from a given metal, and it would be more logical to call all the other results "fictitiously low." This it will readily be admitted is a more usual state of affairs in ordinary testing.

Mr. Dix admits that "no one test bar can represent the physical properties in a casting," but with this idea well understood by both producer and consumer, the best plan is undoubtedly to use test bars that show definitely the highest possibilities of the metal, instead of aiming at such an indefinite objective as "the average physical properties of the general run of castings." This may mean something entirely different in different foundries, and is of no more value to the user of some highly specialized casting than the definite value obtained from the best possible test bar.

Some interesting observations along this line were published in Vol. XI of the Journal of the American Institute of Metals, pages 435 to 442, in discussing a paper on "Some Comparative Tests on Test Bars and Actual Castings." The results of Dr. Langenberg on manganese bronze, and his remarks quoted on page 442, are particularly pertinent to the present discussion.

Mr. Dix, Jr. MR. E. H. DIX, JR. (*Author's closure by letter*).—The author wishes to thank Messrs. Clamer and Comstock for their kind comments relative to his paper, and desires to emphasize the point that the success attained with the $\frac{1}{4}$-in. web is due to the proper proportioning of the riser above the web. The thin web is continued just far enough to allow for a saw cut and is then flared out as abruptly as good molding practice will allow. In this way the heat from the riser prevents the web from freezing too quickly and thus allows the riser to feed into the test bar until the latter is solid.

Mr. Dix, Jr.

In reference to Mr. Comstock's contention that the method of pattern No. TB–2S should be used in preference to the one selected, it is desired to point out that this bar does not meet three of the four requirements stated in the introductory paragraph of the paper:

1. It is difficult to cut the specimen from the coupon with the type of band saw found in the ordinary non-ferrous foundry, and it also requires considerable machining afterwards.

2. It requires too much metal. Weighing about 33 lb., it would require at least one-fourth of the metal poured from a No. 40 pot.

3. It gives physical properties considerably higher than can be obtained in actual castings, and when all is said and done, in spite of every warning to the contrary, designers habitually take specification values and use them in their calculations. Thus specification values for pattern No. TB–2S would lead to a serious reduction in the calculated factor of safety.

The author would disagree with Mr. Comstock's statement that a test bar does not fulfill its function as a measure of the quality of metal unless it is cast so as to obtain the best possible results. The same argument has been advanced for chill casting test bars of aluminum alloys, but it has met with decided disapproval in this country.

SOME MECHANICAL PROPERTIES OF HOT-ROLLED MONEL METAL.[1]

BY P. D. MERICA, R. G. WALTENBERG AND A. S. MCCABE.

During the past two years the Research Department of The International Nickel Co. has been securing new and additional data on the mechanical properties of monel metal, some of which have been considered of sufficient general interest to reproduce and discuss here. A more accurate knowledge of these properties has become necessary on account of the increasing use of this metal in machine construction for parts requiring both strength and resistance to corrosion.

Mean values of the tensile properties of hot-rolled (or hammered) monel metal rods are given in Table I as computed from the results of 500 tensile tests during 1919 and 1920. The average proportional limit of hot-rolled monel metal varies from 35,000 to 49,000 lb. per sq. in., and is approximately 80 per cent of the yield point. Calculation of several of the arbitrary, so-called "quality factors" of monel metal has shown it to possess a remarkable degree of toughness as compared with other metallic materials, including alloy steels.

The shear, or torsional properties, of hot-rolled monel metal stand in a definite ratio to its tensile properties. Thus, the average proportional limit in torsion, or shear, varies from 20,000 to 29,000 lb. per sq. in., or from 55 to 67 per cent of that in tension. The average elastic moduli of hot-rolled monel metal are:

Shear, or torsion modulus	9 600 000 lb. per sq. in.
Young's modulus	25 400 000 " "
Poissons' ratio	0.33

The resistance to alternating stresses of hot-rolled monel metal was studied in a rotary beam type of machine. This metal will withstand approximately seventy-five million alternations of tension and compression at a maximum fiber stress of 38,000 lb. per sq. in. and approximately two million alternations at 43,000 lb. per sq. in., the relation between maximum fiber stress and number of alternations being given by the formula:

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[1] The alternating stress tests were carried out at the Bureau of Standards by R. G. Waltenberg; the other tests were made at the Research Department of the International Nickel Co., at Bayonne, N. J.

$$S = 69{,}600\ N^{-0.0333}.$$

TENSILE PROPERTIES.

During the course of each year there are made at the testing laboratory of The International Nickel Co., at Bayonne, a number of routine tensile tests of monel metal hot-rolled rods. These tests display the normal variations in values even in rods of the same size and manner of rolling and of approximately the same chemical composition which are to be expected in tests of hot-rolled material. In order to gain a somewhat clearer statistical picture of these properties of monel metal, these individual tests have been averaged at two times; *viz.*, in 1916 for the year 1916, and later in 1920 for the years 1919–1920, the averages for the former period having been obtained by selecting 50 individual tests within each group of sizes corresponding to the U. S. Navy Department specifications, those of the latter period, however, by averaging, first, all of the tests for each size of rod, and

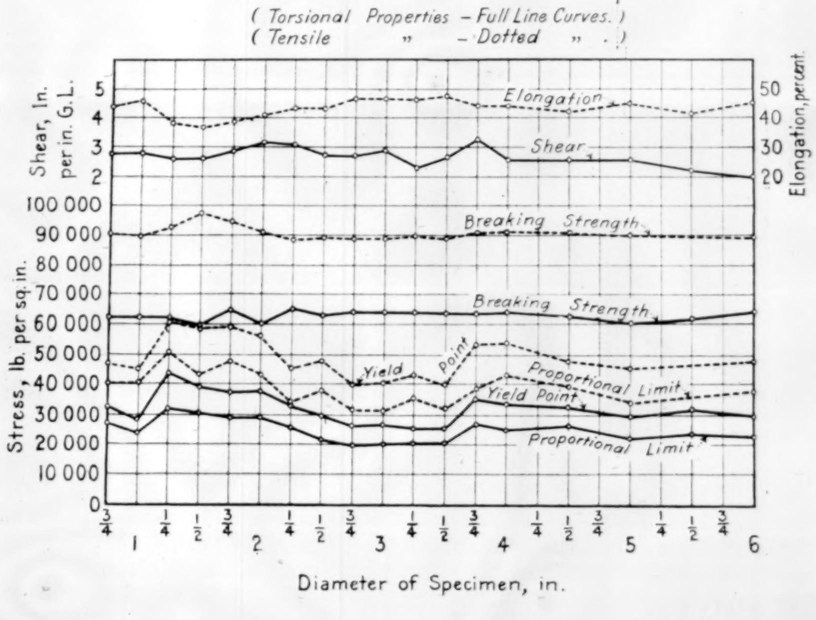

FIG. 1.—Comparison of Tensile and Torsional Properties of Hot-Rolled Monel Metal for Various Sizes.

then calculating from these the weighted average of each specification group. Each such group included from 50 to 100 tests.

TABLE I.—AVERAGE TENSILE PROPERTIES AND HARDNESS OF HOT-ROLLED MONEL METAL.

Group Sizes of Hot-Rolled Rods.	Average Tensile Properties				Average Brinell Hardness 1919–1920		Average Shore hardness, S.	Some Ratios of Mechanical Properties.					Some Products or Quality Factors.			
	Proportional Limit, $P. L.$, lb. per sq. in.	Yield Point, $Y. P.$, lb. per sq. in.	Tensile Strength, T, lb. per sq. in.	Elongation in 2 in., e, per cent.	500 kg., B_{500}	3000 kg., B_{3000}		$\frac{P. L.}{Y. P.}$	$\frac{Y. P.}{T}$	$\frac{T}{B_{3000}} \times 0.1$	$\frac{P. L.}{S} \times 0.01$	$\frac{B_{3000}}{B_{500}}$	$T e \times 10^{-6}$	$Y e \times 10^{-6}$	$\frac{Y. P. + T}{2} e \times 10^{-5}$	$\frac{Y. P.}{T} e$
ROUNDS AND SQUARES.																
Up to 1 in. in diameter:																
1916	......	63 100	94 600	40	....	....	......	....	0.67	....	....	....	38	25	32	27
1919–1920	39 700	51 300	91 500	46	113	144	22	0.86	0.56	64	18	1.27	42	23	33	25
$1\frac{1}{16}$ to $1\frac{11}{16}$ in.:																
1916	......	62 000	93 100	39	....	....	......	....	0.67	....	....	....	36	24	30	26
1919–1920	47 700	59 600	93 200	37	130	162	23	0.80	0.64	58	21	1.24	34	22	28	24
$1\frac{3}{4}$ to $2\frac{7}{16}$ in.:																
1916	......	50 100	87 700	42	....	....	......	....	0.57	....	....	....	37	21	29	24
1919–1920	40 200	51 900	90 300	42	127	161	23	0.80	0.57	57	18	1.26	38	22	30	24
$2\frac{1}{2}$ to $3\frac{1}{2}$ in.:																
1916	......	43 800	85 300	44	....	....	......	....	0.51	....	....	....	38	19	28	22
1919–1920	32 200	41 800	88 900	46	120	147	23	0.81	0.47	60	14	1.22	41	19	30	22
Over $3\frac{1}{2}$ in.:																
1916	......	47 300	84 800	43					0.56				36	20	28	24
1919–1920	37 200	50 300	88 400	43	120	152	24	0.79	0.57	61	16	1.26	38	22	30	24
HEXAGONS.																
All Sizes:																
1916	......	60 700	87 800	40	....	....	....	......	0.69	....	....	....	35	24	30	28
1919–1920	49 100	60 600	92 300	38	133	167	25	0.81	0.66	57	19	1.25	35	23	29	25
RECTANGLES.																
All Sizes:																
1916	......	56 400	85 600	42	....	....	....	......	0.66	....	....	....	36	24	30	28
1919–1920	35 800	47 000	89 800	47	114	144	24	......	0.53	62	15	1.26	42	22	33	25
Averages 1916								......	0.62	....	....	....	36	22	29	25
Averages 1919–1920								0.80	0.57	58	17	1.25	38	22	31	24

These averages, representing the mean tensile properties of hot-rolled monel metal rod, are reproduced in Table I and Fig. 1, together with the corresponding values of Brinell and Shore hardness and some numerical relations between these properties calculated from them.

All of the tests represented by these averages were made on a 200,000-lb. Olsen testing machine using a cross-head testing speed of 1.17 in. per minute in determining tensile strength, and either 0.048 or 0.28 in. per minute in determining yield point. The proportional limit was determined with a Berry strain gage or Ewing extensometer. The yield point in the 1916 tests was determined with dividers and the

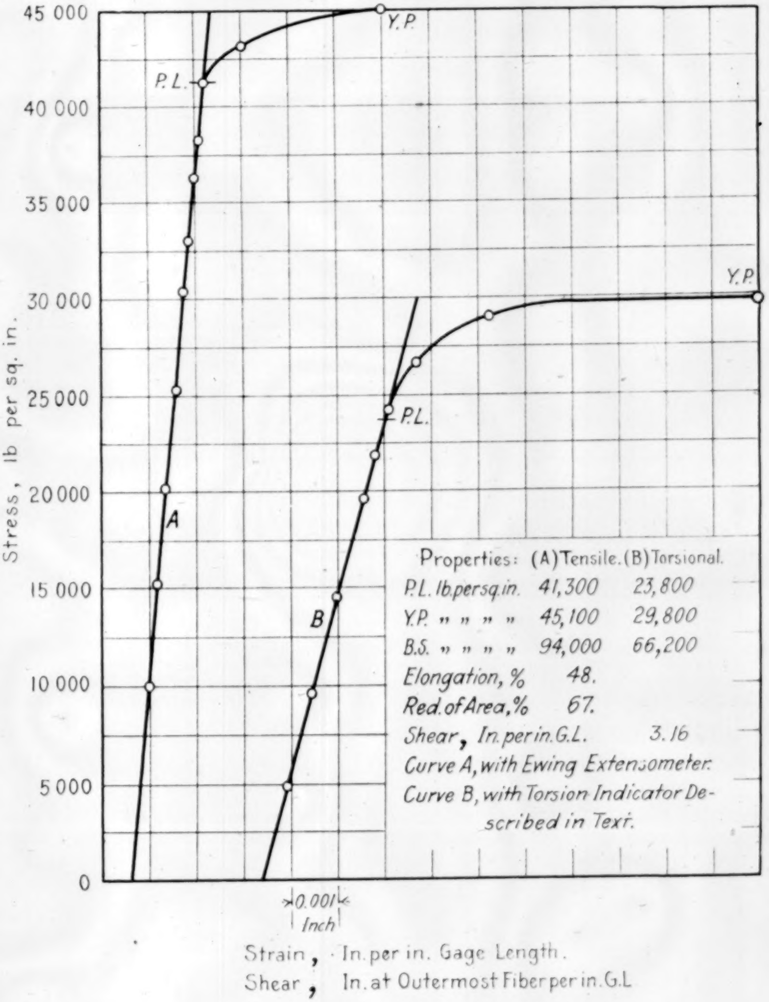

FIG. 2.—Typical Stress-Strain Curves of Hot-Rolled Monel Metal in the Tension and in the Torsion Tests.

drop of the beam, that in the later tests sometimes with dividers but generally with a strain gage or extensometer, the stress being considered as the yield point at which the specimen yielded 0.01 in. in 2 in. or 0.5 per cent. In the latter case the testing speed was 0.048 in. per minute.

In view of the indefinite and arbitrary character of the yield point definition a few tests were made to determine the relation between the values of yield point determined by these three methods and with three different speeds of testing. The results of these tests made on nine samples of the same ½-in. diameter rod tested with wedge grips are given in Table II. It will be seen that at all speeds the values as given by the drop of the beam and with the strain gage were identical, that the value given by the dividers was always greater than this but generally by a very slight amount only, and that the speed of testing exerted a much greater effect on the value than did the method of determination. For moderate speeds of test it would seem that any of the three methods is suitable for monel metal and that they give practically identical results.

TABLE II.—DETERMINATION OF YIELD POINT, LB. PER SQ. IN.

Method of Determining Yield Point.	Testing Speed.											
	0.048 in. per minute.				0.277 In. Per Minute.				1.174 In. Per Minute.			
	Drop of Beam.	By Strain Gage.	By Dividers.	Reading of Strain Gage.[1]	Drop of Beam.	By Strain Gage.	By Dividers.	Reading of Strain Gage.[1]	Drop of Beam.	By Strain Gage.	By Dividers.	Reading of Strain Gage.[1]
Specimens Nos. 1, 2, 3...	49 300	49 300	49 300	40	51 800	51 800	51 800	70	56 800	......	56 800	......
Specimens Nos. 4, 5, 6...	50 250	50 250	55 000	200[a]	50 500	50 500	50 500	105	54 750	54 750	54 750	120
Specimens Nos. 7, 8, 9...	51 300	51 300	51 300	55	52 750	52 750	52 750	135	57 500	57 500	57 500	135
Average, each method...	50 280	50 280	51 860	....	51 680	51 680	51 680	......	56 350	56 150	56 350	......
Average, each speed.....	50 800				51 680				56 270			

[a] Strain gage stopped at 200 and was removed before dividers indicated Yield Point.

[1] Reading of strain gage at moment of indication of Yield by dividers.

The results of proportional limit determinations made with the strain gage and with the Ewing extensometer show good agreement although it is not possible to determine the modulus of elasticity with the former as it is with the latter. Fig. 2 shows a typical stress-strain curve of hot-rolled monel metal rod taken with the Ewing extensometer; this metal exhibits a marked and definite yield point and proportional limit similar to steel and in contrast to the elastic behavior of most non-ferrous materials.

A matter of much interest to manufacturers of metallic materials subject to tensile test and specifications is that of the dispersion of individual values of the tensile properties around the mean value, or in other words, the degree of variation of individual test values from the average one. The table below illustrates this feature of the properties of monel metal and shows the distribution of 106 test values of tensile strength (1916) of hot-rolled rods between $1\frac{3}{4}$ and $2\frac{7}{16}$ in. in diameter.

TENSILE STRENGTH, LB. PER SQ. IN.	NUMBER OF VALUES.	PERCENTAGE.
up to 80,000	1	1
80,000 to 82,500	4	4
82,500 to 85,000	6	6
85,000 to 87,500	22	21
87,500 to 90,000	35	33
90,000 to 92,500	23	22
92,500 to 95,000	11	10
95,000 to 97,500	3	3
over 97,500	1	1
Average 88,800		

From this table it is evident why there must always be a considerable difference between specification and average values, in order that there may not be 50 per cent of the material rejected on test; this is a fact which the engineer does not, perhaps, always realize, although this margin is entirely analogous to his own margin or factor of safety. It will be seen that the values of these tests fall within about ±10 per cent of the mean value.

Of the ratios between various tensile properties and hardness calculated in Table I only two seem to be very uniform and consistent; *viz.*, that of proportional limit to yield point which seems to be fairly constant at about 0.80 (except for the smaller sizes) and that of the Brinell hardness at the two loads. The ratio of tensile strength to Brinell hardness (3000 kg.) varies in the different groups between 570 and 640, or ±6 per cent. It is thus possible to predict only approximately the Brinell hardness from the knowledge of the tensile strength and *vice versa*.

A number of different "quality factors" of metallic materials of construction calculated from the values of the tension test have been suggested from time to time. They are generally stated in terms of energy (required to rupture) and are obtained by the product of the elongation into yield point or ultimate strength. Some of these are calculated in Table III in arbitrary units. It will be observed that the quantity, $Y.P./T \times e$, is the most constant within the various groups, and may, perhaps, best serve in determining in any case whether the metal is of standard quality or not.

As a matter of interest there are given in Table III three of those quality factors for several different materials. Monel metal, it will be seen, requires an unusually large amount of energy to rupture it in the tensile test as compared with steels and non-ferrous materials. This is primarily due to its great ductility as compared with other materials of the same hardness.

TABLE III.

Material.	Tensile Strength, T, lb. per sq. in.	Yield Point, $Y.P.$, lb. per sq. in.	Elongation, e, per cent.	$\frac{T+Y.P.}{2}e \times 10^{-5}$	$Te \times 10^{-5}$	$\frac{Y.P.}{T}e$
S. A. E. No. 3340, high-nickel-chromium steel:						
Quenched and drawn at 800° F.	203 000	180 000	12.5	24	25	11
Quenched and drawn at 1100° F.	130 000	118 000	21	26	27	19
Rolled Manganese Steel:						
11 to 12 per cent Mn, 1 per cent C.	138 000	65 000	35	36	48	17
Annealed Copper.	35 000	10 000?	50	12	17	14
Annealed Sheet High Brass.	45 000	15 000	55	17	25	18
Average for Hot-Rolled Monel Metal.	......	......	....	31	38	24

The figures for the "quality factors" are expressed in terms of energy, but of arbitrary units; it may be observed that to break the ordinary 0.505-in. diameter tension test specimen of monel metal requires:

$$\left(\frac{T+Y}{2} \times 0.2\right)\left(e \times 0.01 \times 2 \times \frac{1}{12}\right) \text{ ft-lb. of energy}$$

or on an average:

$$10^5 \times 30.5 \times 0.2 \times 0.01 \times 2 \times \frac{1}{12} = 1020 \text{ ft-lb.}$$

The average modulus of elasticity in tension (Young's modulus) of hot-rolled monel metal rods as shown by 45 tests with the Ewing extensometer (2-in. gage length) is 25.4×10^6 lb. per sq. in., with a minimum value of 24.5×10^6 and a maximum value of 26.4×10^6 lb. per sq. in.

TORSIONAL PROPERTIES.

The torsion tests were made of eighteen different sizes of hot-rolled, or hammered monel metal rounds and six different sizes of hot-hammered monel metal hexagons. The rounds varied from $\frac{3}{4}$ in. in diameter to 4 in. in diameter in $\frac{1}{4}$-in. steps, and from 4 in. in diameter to 6 in. in diameter in $\frac{1}{2}$-in. steps. The hexagons varied from $\frac{3}{4}$ in.

across flats to 2 in. across flats in $\frac{1}{4}$-in. steps. In order to make these tests as nearly representative as possible twelve specimens, as widely dispersed in the warehouse stock as possible, were selected for each size and kind up to and including 2 in. For sizes above 2 in., six specimens were selected as representative. This distribution of test specimens was considered sufficient to give good average values of the torsional properties of hot-rolled, or hammered, monel metal.

In making these tests the material was twisted without machining up to and including $1\frac{1}{2}$ in., this size being the limit of the capacity of the machine. Above this size a specimen of $1\frac{3}{8}$ in. in diameter and 10 in. gage length was machined in such a manner as to represent an average of the metal in that particular size. The total length of the specimen was 22 in. and the grips were tapered to the gage length at an angle of about 30 deg. All test specimens were solid and not hollow.

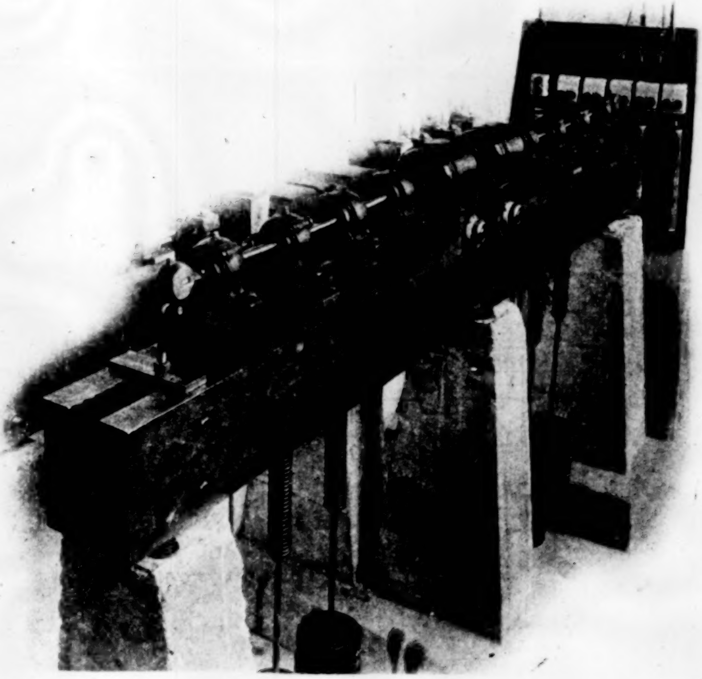

FIG. 3.—Rotating-Beam Machine for Fatigue Tests.

These specimens were twisted in a Riehlé Torsion Machine of 60,000 in-lb. capacity. The twisting speed used in the determination of yield point was 11 deg. per minute, and that of determining the ultimate strength 400 deg. per minute. The torsion indicator used consisted of two grooved wheels centered 10 in. apart on the specimen by set screws and belted by No. 28 gage cotton-covered copper wire to two Wissler Dials. Each dial was clamped to the end of a 90 deg. elbow, each of which swung freely and independently of the other about a bracketed rod. The elbow was weighted at the other end so as to cause the dial to "float" against the tension of the belted copper wire and hence to "float" with the specimen itself, thus eliminating any indication on the dial due to motion or slip between the dial and the specimen. The ratio of the wheel diameter to the dial spindle diameter was about 30 to 1. The dials were divided into 500 divisions and were calibrated directly in radians per division by turning the head of the machine, with the specimen free at the stationary jaw, through several accurately-measured turns.

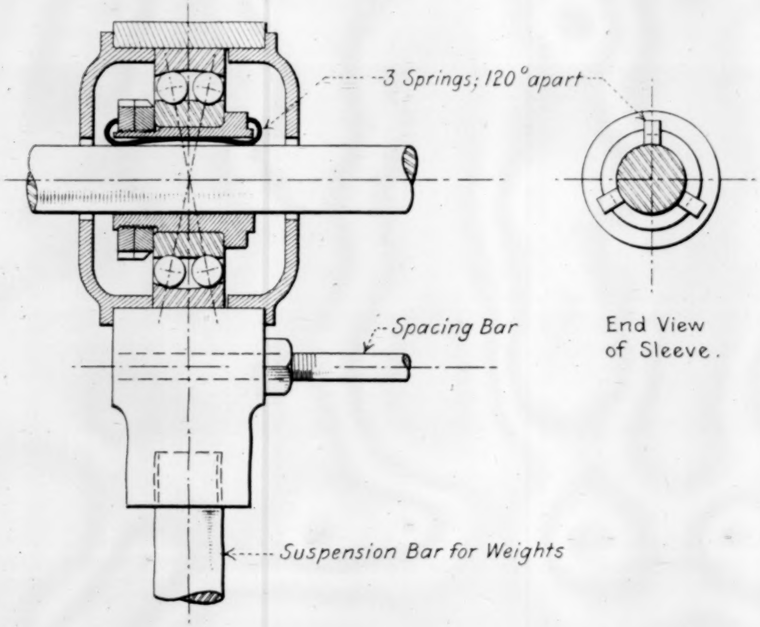

FIG. 4.—Arrangement of Specimen in Bearing.

It was desired to determine a yield point by the use of this indicator which would be comparable with that determined in the tension test; *viz.*, at an elongation of 0.01 in. in 2 in. Therefore, the yield point in torsion was defined as the stress at which the linear shear of the outermost fiber was 0.01 in. per inch of gage length, since the elastic displacement was found to be slightly over twice that in tension. In order to read the value of the yield point in inch-pounds directly on the beam of the machine it was only necessary to calculate in advance, for the size specimen used, the difference to be indicated between the readings of the dials equivalent to the 0.01 in. linear shear.

To carry still further the comparison between torsional and tensile results, a measure of ductility in torsion was desired which would be as easily visualized as the percentage of elongation in a tension test. The angle of twist per inch was unsatisfactory since it varies inversely as the diameter of the specimen. A measure of ductility in torsion was, therefore, defined as the linear shearing displacement, in inches, at the outermost fiber per inch of gage length. This gives a figure which is independent of the diameter of the specimen and which is proportional to the percentage of elongation in 2 in. in a tension test. It is equal to πD times the twists per inch of gage length, where D is the diameter of the specimen in inches. The twist per inch of gage length was easily measured by scribing a fine line on the specimen and, at the completion of the test, measuring the distance in inches between a given number of twists.

The remaining torsional properties were determined in the usual manner and the results computed from the usual formulae. The twist in degrees per inch is also given, although this figure can only be used to compare specimens of the same diameter.

The results shown in Table IV are best summarized by the curves of Fig. 1, and it will be seen that the torsional properties of monel metal are generally proportional to the tensile properties, the tension test averages for 1919–1920 being plotted as dotted lines to the same scale in order to show this relation. The ratios:

$$\frac{P.L._s}{P.L._t}, \quad \frac{Y.P._s}{Y.P._t}, \quad \frac{B.S._s}{B.S._t}, \quad \frac{\text{Shear, in.}}{\text{Elongation, per cent}}$$

have been computed in order to give a quick and convenient means of converting the results of a tension test into approximate results for a torsional test, or *vice versa*.

From the averages given in Table IV a few additional torsional properties of monel metal have been calculated, the most important of these being that of the modulus of elasticity in shear, E_s, which was found to be 9,550,000 lb. per sq. in. as an average of 212 tests on all sizes of rounds and hexagons.

In order to show the general relation between torsion and tension tests Fig. 2 was drawn which shows curves of typical tests. The tension test was made with an Ewing extensometer and the torsion test with the indicator previously described.

TABLE IV.—TORSIONAL PROPERTIES OF HOT-ROLLED AND HOT-HAMMERED MONEL METAL ROUNDS AND HEXAGONS.

Number of Tests.	Material.	Diameter of Specimen, in.	Proportional Limit, P.L., lb. pr sq. in.	Yield Point, Y.P., lb. per sq. in.	Breaking Strength, B.S., lb. per sq. in.	Angle of Twist, deg. per in.	Shear, in. per inch of gage length.	Modulus of Elasticity, E_s million lb. per sq. in.	Ratio $\frac{Y.P._s}{P.L._s}$ (a)	Ratio $\frac{P.L._s}{P.L._t}$ (a)	Ratio $\frac{Y.P._s}{Y.P._t}$ (a)	Ratio $\frac{B.S._s}{B.S._t}$ (a)	Ratio $\frac{\text{Shear, in.}}{\text{Elongation, per cent.}}$
12	$\frac{3}{4}$-in. rounds, hot-rolled, unmachined......	0.758	26 800	32 100	62 000	415	2.75	9.33	1.20	0.67	0.69	0.69	0.054
12	1 -in. rounds, hot-rolled, unmachined......	1.021	23 600	28 000	62 100	314	2.80	9.11	1.18	0.59	0.63	0.69	0.061
24 Average	$\frac{3}{4}$ to 1-in. rounds, inclusive	.....	25 200	30 000	62 000	...	2.78	9.24	1.19	0.63	0.66	0.69	0.058
15	$1\frac{1}{4}$-in. rounds, hot-rolled, unmachined	1.264	31 900	43 300	61 800	236	2.60	9.28	1.35	0.63	0.72	0.67	0.068
12	$1\frac{1}{2}$-in. rounds, hot-rolled, unmachined......	1.499	30 400	38 400	59 500	198	2.60	9.69	1.26	0.70	0.65	0.61	0.071
12	$1\frac{3}{4}$-in. rounds, hot-rolled, machined........	1.377	28 800	36 800	64 400	239	2.88	9.41	1.28	0.60	0.62	0.68	0.075
12	2 -in. rounds, hot-tolled, machined........	1.373	29 000	37 700	60 000	263	3.16	10.09	1.30	0.67	0.67	0.66	0.077
6	$2\frac{1}{4}$-in. rounds, hot-rolled, machined........	1.366	25 700	33 300	64 750	256	3.06	9.96	1.30	0.76	0.74	0.73	0.070
57 Average	$1\frac{1}{4}$ to $2\frac{1}{4}$-in. rounds, inclusive	.....	29 700	38 600	61 800	...	2.83	9.64	1.29	0.67	0.68	0.67	0.072
10	$2\frac{1}{2}$-in. rounds, hot-rolled, machined........	1.370	21 600	29 700	62 700	234	2.67	9.68	1.38	0.58	0.63	0.70	0.061
6	$2\frac{3}{4}$-in. rounds, hot-rolled, machined.......	1.375	19 200	26 000	63 800	220	2.64	10.27	1.36	0.62	0.66	0.72	0.057
10	3 -in. rounds, hot-rolled, machined........	1.381	19 800	26 400	63 600	252	2.85	9.35	1.34	0.64	0.66	0.72	0.061
6	$3\frac{1}{4}$-in. rounds, hot-rolled, machined........	1.353	20 000	25 200	63 300	193	2.28	9.70	1.26	0.57	0.59	0.71	0.050
9	$3\frac{1}{2}$-in. rounds, hot-rolled, machined........	1.374	20 000	25 100	63 300	227	2.61	9.39	1.25	0.62	0.64	0.72	0.055
41 Average	$2\frac{1}{2}$ to $3\frac{1}{2}$-in. rounds, inclusive	.....	20 200	26 700	63 300	...	2.64	9.62	1.32	0.61	0.64	0.71	0.057
6	$3\frac{3}{4}$-in. rounds, hot-hammered, machined....	1.365	26 400	34 400	63 000	269	3.21	9.89	1.30	0.69	0.65	0.70	0.077
6	4 -in. rounds, hot-hammered, machined....	1.377	24 700	33 000	63 500	207	2.48	9.52	1.33	0.59	0.62	0.70	0.057
6	$4\frac{1}{2}$-in. rounds. hot-hammered, machined....	1.369	24 800	32 200	62 150	212	2.53	9.82	1.31	0.64	0.67	0.69	0.060
6	5 -in. rounds, hot-hammered, machined....	1.375	21 800	29 400	60 000	213	2.56	9.88	1.35	0.65	0.65	0.67	0.057
6	$5\frac{1}{2}$-in. rounds, hot-hammered, machined....	1.356	23 700	31 900	61 400	182	2.16	9.66	1.34	....	....	0.65	0.053
1	6 -in. rounds, hot-hammered, machined....	1.377	22 200	29 400	64 000	160	2.92	....	1.33	0.59	0.62	0.72	.....
31 Average	$3\frac{3}{4}$ to 6-in. rounds, inclusive..............	.....	24 200	32 200	62 100	...	2.57	9.75	1.32	0.63	0.64	0.69	0.060
12	$\frac{3}{4}$-in. hexagons,hot-hammered, unmachined	0.763	27 100	41 900	64 600	100	0.70	9.18	1.54	....	0.63	0.77	.....
12	1 -in. hexagons, hot-hammered, unmachined	1.006	28 300	41 900	65 800	84	0.70	...	1.48	0.75	0.65	0.69	.....
12	$1\frac{1}{4}$-in. hexagons, hot-hammered, unmachined	1.265	24 500	37 200	63 700	66	0.70	9.00	1.52	0.49	0.62	0.68	.....
12	$1\frac{1}{2}$-in. hexagons, hot-hammered, unmachined	1.499	24 800	36 100	63 900	63	0.80	9.37	1.46	0.49	0.60	0.67	.....
12	$1\frac{3}{4}$-in. hexagons, hot-hammered, machined....	1.371	21 100	28 250	61 500	258	3.10	9.89	1.34	0.47	0.50	0.68	0.084
12	2 -in. hexagons, hot-hammered, machined....	1.368	23 250	30 600	62 100	278	3.30	9.86	1.36	0.57	0.55	0.70	0.086
72 Average	$\frac{3}{4}$ to 2-in. hexagons, inclusive..............	.....	24 800	36 000	63 600	...	1.55	9.47	1.45	0.55	0.59	0.69	0.085

[a] The subscript s denotes "in shear," the subscript t in tension.

It should be emphasized that all of the torsion tests were carried out with solid test bars. Inasmuch as the central fibers are not stressed as greatly as the outer fibers the values of the torsional properties so obtained hold strictly only for solid bars in torsion and may not be strictly equal to the true shearing properties as determined on hollow test-bars of large diameter and thin wall.

FATIGUE TESTS.[1]

The fatigue tests were made on rotary beam fatigue testing machines similar to those described by F. M. Farmer, *Proceedings*, Am. Soc. Test. Mats., Vol. XIX, p. 709 (1919). This type of machine is also described in "Tests of Metals," p. 439, 1893, and p. 577, 1895. The specimen forms a cylindrical beam which is supported at the ends and equally loaded at two symmetrical intermediate points. Alternations of stress are obtained by rotating the beam about its axis; in these tests the specimens were rotated at 1750 revolutions per minute. The machines used had end supports 24 in. (609.6 mm.) apart and the specimen was loaded at two points 8 in. (203.2 mm.) apart and 8 in.

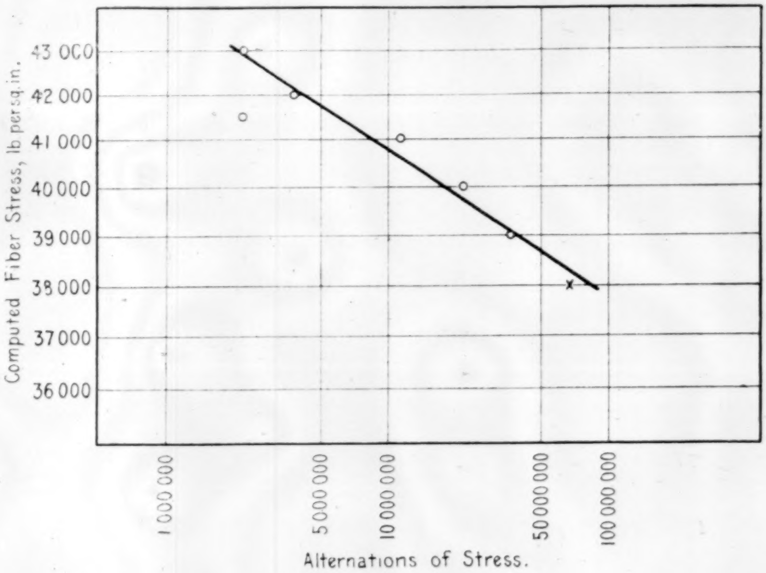

FIG. 5.—Logarithmic Plot of Results of Fatigue Tests of Monel Metal of Proportional Limit, 36,600 lb. per Sq. In.

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[1] This portion of the paper is published by permission of the Director of the Bureau of Standards.

from the end supports. Thus, the specimen had an 8-in. length over which the bending moment was uniform.

Three machines, equipped with single-race ball bearings mounted on gimbals, were used in a preliminary investigation. The specimens were adapted to the bearings by collapsible bushings which were adjusted by tapering collars. This arrangement was not satisfactory. It was practically impossible to center the specimens in the bearings and a small eccentricity would cause vibration of the specimen. Another objection to this method of fitting the specimen to the bearing was the difficulty of determining when the proper pressure had been applied to the tapering collars. A small variation of this pressure would either allow the specimen to slip in the bearings or would bind the bearing.

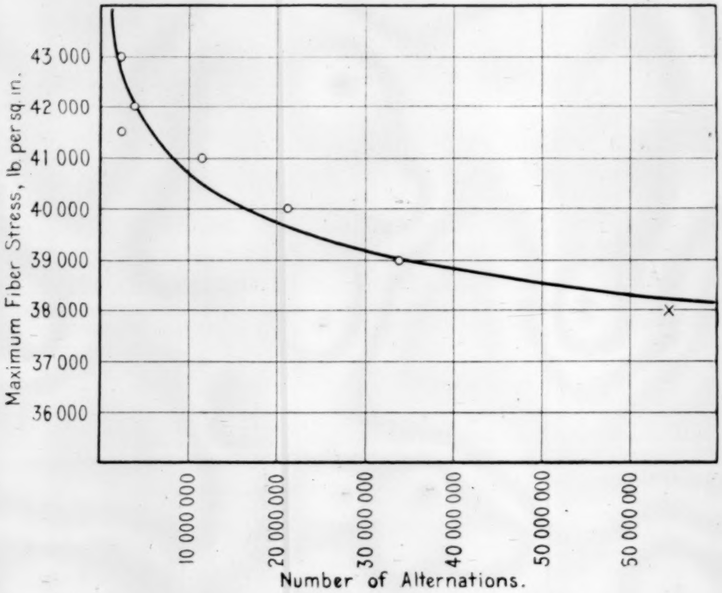

FIG. 6.—Results of Fatigue Tests of Monel Metal Plotted Directly Without Logarithmic Coordinates.

Another set of seven machines, such as are shown in Fig. 3, were constructed with SKF self-aligning ball bearings, the method used for attaching the specimen to the bearing having been recommended by the manufacturers of the bearings. A sleeve was placed on the inner race of the bearing with a force fit. This sleeve had a sliding fit on the specimen and contained three flat springs 120 deg. apart which gripped the specimen. This arrangement of the bearing with housing and sleeve has proven satisfactory and is shown in Fig. 4. Weights to produce the desired stress were suspended from the bearing housings by helical springs.

Each machine was driven by a $\frac{1}{4}$-h.p., 110 volt direct current motor connected to the specimen by a leather disk flexible coupling. The total number of revolutions were registered by a Veeder counter connected to the other end of the specimen by a fork and pin coupling.

The specimens were run until they failed. In every case this failure was a crack which extended about half way through the specimen from one side. This would cause the specimen to vibrate badly, thereby putting a heavy load on the motor. The motor power line was fused to three amperes and the burning out of this fuse would stop the machine. It was observed that the time which elapsed from the first indication of failure to the stopping of the machine was less than one minute.

The specimens used in these tests were 28 in. (711 mm.) long, 0.75 in. (19 mm.) in diameter, and with a reduced section in the middle of 0.55 in. (14.2 mm.) in diameter. This reduced section was an arc 5 in. (127 mm.) long with a radius of 32 in. (813 mm.). It was finished by polishing with No. 00 American emery paper.

As the specimen has its smallest diameter in the middle of the beam the maximum fiber stress would be at that section. The bending moment was calculated from the formula:

$$\mathrm{M} = Pa + \frac{Wl}{8} = 8\,P + 10.2$$

where P = load, in pounds, on each bearing.
a = distance of load from support (8 in.).
W = weight of beam (3.4 lb.).
l = length of beam (24 in.).

As we have disregarded the non-uniform distribution of weight due to the reduced section in the above formula the bending moment is too high. The error is about 1 in-lb. and is, therefore, negligible.

The maximum fiber stress was computed from

$$S = \frac{Mc}{I}$$

where S = maximum fiber stress in pounds per square inch, M = bending moment in inch-pounds, c = distance from neutral axis to outer fiber = $d/2$ where d is the diameter in inches at its smallest section, and I = moment of inertia.

$$\text{Then } S = \frac{8P + 10.2}{0.0982d^3}$$

The computed maximum fiber stress differs from the actual stress because of two assumptions. The first assumption is that the stress distribution at the center of the reduced section is the same as that at the center of a long cylinder of the same diameter. Therefore, when the computed maximum fiber stresses are below the proportional limit they are somewhat smaller than the actual stress. This difference is probably negligible with a section such as we have used. The other assumption is that Hooke's law applies above the proportional limit. Since the computed stresses in these tests lie well above the proportional limit and in some cases above the yield point it is believed that they are somewhat higher than the actual stresses in the beams.[1]

The material tested was hot-rolled monel metal, all the specimens being taken from one ingot and billet. The mechanical properties of this material as determined by the usual tests and chemical analysis were as follows:

Proportional limit	36 600 lb. per sq. in.
Yield point (drop of beam)	40 700 " "
Ultimate strength	88 000 " "
Elongation in 2 in.	48.5 per cent
Reduction of area	66 " "
Brinell hardness (3000 kg.)	143
Carbon	0.19 per cent
Manganese	1.30 " "
Sulfur	0.03 " "
Silicon	0.04 " "
Iron	2.10 " "

The results of the alternating stress tests are shown in Table V and Figs. 5 and 6. Results are included only of the specimens tested with the improved machines. An alternation is considered to be a complete cycle of stress corresponding to one revolution of the beam. Some tests are indicated which were questioned because of conditions in the tests which would tend to increase the stress in the beam and, therefore, give low values for the endurance. It can be seen that some of the results questioned were higher than others obtained in tests which appeared to be run under proper conditions. The average of what were considered good results are shown in Figs. 5 and 6. Fig. 5 is plotted with logarithmic scales.

The results on different specimens varied considerably with computed stresses at and above 41,500 lbs. per sq. in. The explanation of this variation may be as follows: With computed stresses at and above 41,500 lb. per sq. in., the reduced section became hot—over 100° C.—

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[1] Obviously the error amounts to a fraction only of the difference between the apparent computed stress and that of the proportional limit.

after a few minutes run. Later, after about 50,000 revolutions some of these specimens became cooler—cool enough to be touched with the hand without discomfort—and in every case where the specimen cooled it stood a much larger number of alternations than those specimens which did not cool. It is possible these specimens may have cooled due to a decrease in the vibration brought about by the bearings adjusting themselves to the position of the specimen.

TABLE V.—RESULTS OF ALTERNATING STRESS TESTS.

Specimen No.	Diameter, in.	Load on each Bearing, lb.	Computed Stress, lb. per sq. in.	Alternations to Rupture.	Remarks.
3 F	0.551	87.99	43 490	84 500	No play in suspension springs.
20 F	0.551	87.00	43 000	86 000	Good.
8 F	0.547	85.06	43 000	4 239 000	Good.
Average				2 162 700	
21 F	0.552	85.40	42 000	156 000	Good.
16 F	0.551	84.95	42 000	122 000	Good.
12 F	0.554	86.33	42 000	14 256 000	Good.
1 F	0.553	85.87	42 000	578 000	Good.
Average				3 778 000	
24 F	0.551	83.92	41 500	260 000	Vibrated.
11 F	0.554	85.29	41 500	550 000	Vibrated.
15 F	0.554	85.29	41 500	3 959 000	Good.
10 F	0.552	84.38	41 500	464 000	Good.
Average				2 211 500[a]	
5 F	0.547	81.09	41 000	16 371 000	Good.
13 F	0.549	81.99	41 000	6 475 000	Good.
Average				11 423 000	
2 F	0.5435	77.48	40 000	10 978 000	Not broken, worn in grip.
9 F	0.549	79.96	40 000	4 945 000	Vibrated.
18 F	0.549	79.96	40 000	25 546 000	Good.
19 F	0.549	79.96	40 000	16 932 000	Good.
Average				21 239 000	
4 F	0.549	77.93	39 000	12 965 000	Not broken, worn in grip.
6 F	0.551	78.86	39 000	10 051 000	Not broken, worn in grip.
23 F	0.550	78.36	39 000	22 123 000	Not broken, worn in grip.
7 F	0.551	78.80	39 000	35 416 000	Good.
22 F	0.5485	77.70	39 000	32 075 000	Good.
Average				33 745 500	
14 F	0.551	76.73	38 000	58 068 000	Vibrated.
17 F	0.549	75.90	38 000	70 648 000	Broke in bearing.

[a] Averages include only results which were obtained under proper conditions.

A number of observers have found the relation between the stress and the number of repetitions in fatigue tests to be $S = KN^m$, where S is the maximum fiber stress, N is the number of repetitions, and K and m are experimentally determined constants depending on the material.

This type of formula gives a straight line when plotted on logarithmic scales. A straight line which approximates the results on monel metal is shown in Fig. 5, the equation of this line being $S = 69{,}600\ N^{-0.0333}$. It may be recalled that in these tests the computed stress is too high and that the difference between the computed stress and the actual stress is increasing with increase of stress.

It will be seen that we have found no "endurance limit"—at least for a relatively small number of stress alternations—such as some observers have found in fatigue tests of steels. This endurance limit has been defined as the stress at and below which a material will stand an unlimited number of repetitions of stress.[1] The plot of the logarithms of the stress as ordinates and the logarithms of the number of repetitions as abscissae deviates from a straight line and becomes nearly horizontal at the endurance limit. It would be of value to know if monel metal has an endurance limit, but if this limit is not apparent above 37,500 lb. per sq. in. it cannot be determined readily on account of the time required for a test to destruction (perhaps as much as one year). However, additional tests are being run at stresses around 38,000 lb. per sq. in. in an attempt to obtain indication of such an endurance limit.

Acknowledgment.—Appreciation is here expressed of the valuable suggestions of Messrs. H. L. Whittemore and R. S. Johnston in connection with the alternating stress tests and of the aid of Mr. R. S. Hatch in carrying out the torsion tests.

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[1] Moore and Kommers, *Iron Age*, 105, p. 1595 (1920).

DISCUSSION.

Mr. Kommers.

MR. J. B. KOMMERS.—I should like to speak of the results that Mr. Merica has obtained as compared with some of the results which we obtained at the University of Illinois in testing a great variety of steels. We found that all of our steels showed a well-defined endurance limit, below which unit stress we could go to 100,000,000 cycles of stress without getting failure. A significant thing in this test of Mr. Merica's is that he has gone out to 75,000,000 cycles and still has found no endurance limit. It may be that if the tests are continued just a little further, perhaps to 100,000,000 or 200,000,000 the endurance limit will appear.

We found one steel which gave the same kind of result as Mr. Merica's in showing an endurance limit higher than the proportional elastic limit. This material was an 0.02-per-cent carbon steel. We found the endurance limit was 26,000, the proportional limit was 16,000, and the yield point 19,000 lb. per sq. in. There was only one other steel which approached such a high ratio of endurance limit to proportional limit, and that was an 0.93-per-cent carbon steel which we tested with three different heat treatments, giving a pearlitic, a sorbitic and a troostitic structure. The pearlitic and troostitic structures had endurance limits about equal to their proportional limits.

The investigation which we are carrying on was limited to ferrous metals, so that we have no information regarding the non-ferrous metals with which Mr. Merica is working.

A PROPOSED METHOD OF ESTIMATING THE DENSITY AND STRENGTH OF CONCRETE AND OF PROPORTIONING THE MATERIALS BY THE EXPERIMENTAL AND ANALYTICAL CONSIDERATION OF THE VOIDS IN MORTAR AND CONCRETE.

By Arthur N. Talbot.

This paper enunciates relations between the strength of concrete and the cement and voids contained therein. It proposes the study of fine aggregate through a determination of the voids in mortars made up with different proportions of cement and varying amounts of mixing water. Characteristic mortar curves giving the relation between the mortar voids and the ratio of fine aggregate to cement, both for the basic water content and for water contents in excess of this, are found to be useful in the calculation of voids in concrete mixtures which may be made up. Analytical relations are developed which permit these characteristic mortar curves to be used in proportioning the cement, fine aggregate and coarse aggregate when designing concretes of a required density and strength, and in estimating the probable strengths of specified mixes made with a given fine aggregate. The effect of the amount of mixing water upon the strength and density of concrete is also considered. The method enables a comparison of aggregates to be made and gives a way of proportioning the mix when an inferiorly graded aggregate must be used. It is found convenient to use the absolute volumes of the ingredients in terms of a unit of volume of the concrete in place, and for this purpose the specific gravity of the material must be known. The resulting values may be translated into bulk or weight when the voids or bulk weights of the materials in the condition obtaining on the work are known. The method is considered to be applicable within the limits of the materials and mixes ordinarily used for Portland-cement concrete. It is believed that the method will be useful (1) for the comparison and acceptance of aggregates, (2) in the design of concrete mixtures for definite densities and strengths, (3) for judging the influence of a change in the volume of the mixing water, (4) for finding the amount of mixing water, (5) for estimating the strengths that may be expected with given concrete mixtures.

PRINCIPLES AND METHODS.

The following paragraphs are given to show the purport of the paper, to indicate something of the methods of the tests and of the analysis, and to outline principles affecting the relation of the ingredients to the strength and density of the concrete.

1. For a given amount of cement per unit of volume of concrete in place (the quality of the cement and the quality and nature of the aggregate remaining the same, but the gradation of the aggregate varying), the greater strength is found in a concrete that has the smaller amount of voids and a lesser strength in one having the larger amount of voids (the voids being taken as the space occupied by the water and air). A definite relation exists between the amount of the voids and the strength of the concrete. The percentage of voids may, therefore, be taken as an index of the strength of the concrete.

2. For different amounts of cement and different gradations oi the aggregate (the quality of the cement and the quality and nature of the aggregate remaining the same), the strength of the concrete varies with the ratio of the amount of cement used in a unit of volume of concrete to the voids in this volume (or the reciprocal of this ratio may be used), and the strength may be taken to be a function of this cement-voids ratio. A relation which is found to be still better is that between the strength and the ratio found by dividing the absolute volume of the cement by the sum of the voids in the concrete and the absolute volume of the cement, which may be termed the cement-space ratio.

3. If the amount of mixing water be varied in such a way as to change the bulk of the concrete, the strength will still be a function of the cement-voids ratio of the resulting concrete, though the function may differ from that which applies at another water content.

4. For the usual concrete mixtures the bulk of the coarse aggregate is less than the bulk of the concrete, or, in other words, the bulk of the mortar in a given volume of concrete is greater than the voids in the coarse aggregate alone (using the term mortar to include the cement, fine aggregate, and water). For such mixtures the voids in the concrete may then be considered to be made up of the water and air voids in the mortar. The density of the mortar for the consistency used in the concrete is, therefore, an important factor in determining the strength of the concrete.

5. If the amount of the water and air voids in the mix of mortar to be used in making the concrete is known (using the term mortar to mean the combination of cement, fine aggregate, and water which enters into the concrete), the voids in a resulting concrete may be

calculated and the corresponding cement-voids ratio or cement-space ratio may be used as an index of the strength of the concrete.

6. By determining the voids in mortars made with a given fine aggregate but with varying proportions of cement, a characteristic mortar voids curve giving the relation between the mortar voids and the ratio of fine aggregate to cement may be made up for any given fine aggregate, and information will then be available on which to base calculations for voids and strength of concrete made with definite proportions of cement, fine aggregate, coarse aggregate, and water.

7. By determining the voids in various mortar mixes made with different fine aggregates of the same character and thus obtaining characteristic mortar voids curves of the given fine aggregate, comparisons may be made of the relative densities and probable resulting strengths of concretes made up with these mortars and with assumed volumes of coarse aggregate.

8. Knowing the characteristic mortar curve of a fine aggregate, (the general nature and quality of the aggregate otherwise being known), the proportions of the mix required to give a specified strength (including the amount of cement, fine aggregate and coarse aggregate) may be calculated with a fair degree of accuracy.

9. The foregoing principles and methods are most readily applied by the use of the absolute volumes of the cement, fine aggregate, and coarse aggregate; but if the voids in the fine aggregate and in the coarse aggregate in a dry state or in the condition obtaining on the work are known, or the relation between the weights of the aggregate by bulk and by solid volume, the bulk of the fine aggregate and of the coarse aggregate required to make a unit of volume of concrete may be readily determined from the absolute volumes given by the calculations already referred to.

10. If the mixture is such that the voids in the aggregate are not fully filled by the mortar, the mortar voids will not be the measure of the voids in the concrete; but if the voids in the concrete are known, the ratio of the cement to the voids in the concrete will still be an indication of the strength of the concrete, except in the more extreme cases.

11. The amount of voids in a specified mix of mortar may be used to determine the acceptability of a given fine aggregate.

12. The method may be used to design the mix of the concrete whatever the amount of cement used and whatever the ratio of coarse aggregate to fine aggregate, though when the mortar does not fill the voids in the coarse aggregate this feature must have consideration.

13. In making the mortar test of a fine aggregate, the voids should be determined for increasing amounts of mixing water. The amount of water that gives the minimum volume of the mortar (greatest density and least voids) may be termed the basic water content. The characteristic mortar voids curve made up from values of the voids for minimum volume of mortar may be termed the basic characteristic mortar voids curve. The basic water content permits a very good consolidation of the particles of the mass when put into the mold; more water swells the mixture, as it also adds to the mobility of the mixture. For other water contents, giving the wetter consistencies, such as for example a 1.20 basic water content, characteristic mortar voids curves may be made up from the voids obtained with the specified water content ratios in the tests already made. If a larger amount of water than the basic water content is to be used in the concrete, the characteristic curve for that proportionate water content should be used in the calculations. Generally, for the consistencies used in concrete work, the water content will range from 1.10 to 1.40 times the basic water content.

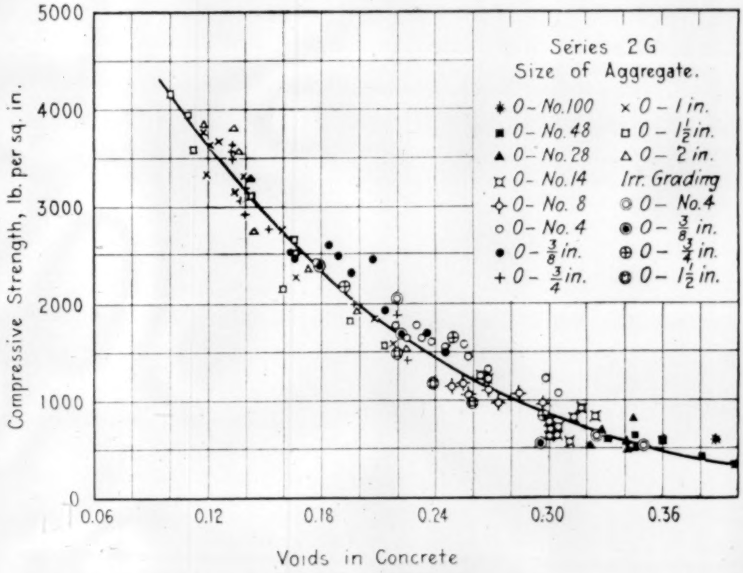

FIG. 1.—Voids and Compressive Strength of Concrete.—Series 2 G.

The foregoing principles have reference principally to the effect of gradation of particles and of the space in the concrete between particles upon the compressive strength of the concrete. Neither the structural strength of the aggregate nor the quality of surface which promotes adhesion (for which the word adhesibility may be coined) is taken into account; these may need separate consideration. The relations between strength of concrete and the amount of cement and voids in the concrete are of course subject to the variations inherent in fabricated materials. Their applicability is also affected by the errors of measurement involved in the processes of the tests.

VOIDS AND COMPRESSIVE STRENGTH OF CONCRETE.

In Fig. 1 are plotted the results of tests made at the University of Illinois in 1919 in cooperation with Committee C-9; the ordinates represent compressive strength at 28 days and the abscissas voids in the concrete. In these tests, including what would be termed mortar mixtures, ten groups of aggregates were used. The range in size of particle for the several groups by sieve sizes was 0–No. 48, 0–No. 28, etc., to 0–1, 0–1½ and 0–2 in. In all cases there was a regular gradation from fine to coarse according to an adopted equation, but each group included eight or ten gradations. At one end of a group the fine praticles predominated, at the other end the excess of coarse particles gave a "coarse mix." The series included, in all,

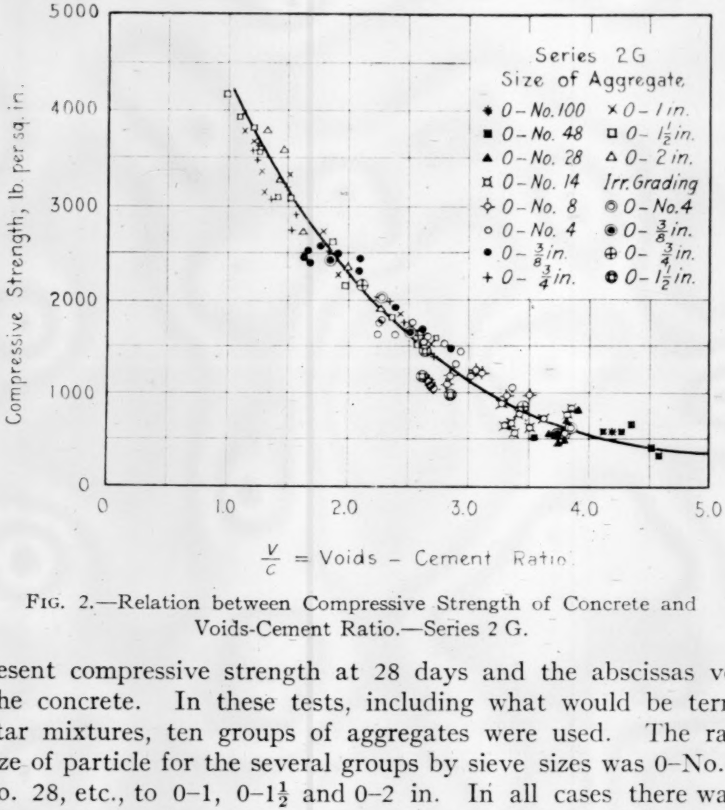

FIG. 2.—Relation between Compressive Strength of Concrete and Voids-Cement Ratio.—Series 2 G.

88 of these regularly graded aggregates. In addition to these, 12 irregularly graded mixtures of fine and coarse aggregate were used. A single mixture with 0–No. 100 sand is included. The same proportion of cement by loose volume was used in all the specimens—one part of cement to 5 parts of mixed aggregate. Due to differences in the bulking of the mixture the amount of the cement in the resulting concrete varies somewhat (a result which is always present in concretes proportioned by loose volume), ranging from say 0.17 cu. ft. of cement by bulk per cubic foot of concrete for the finer mixtures of each maximum size of aggregate to 0.21 cu. ft. per cubic foot for

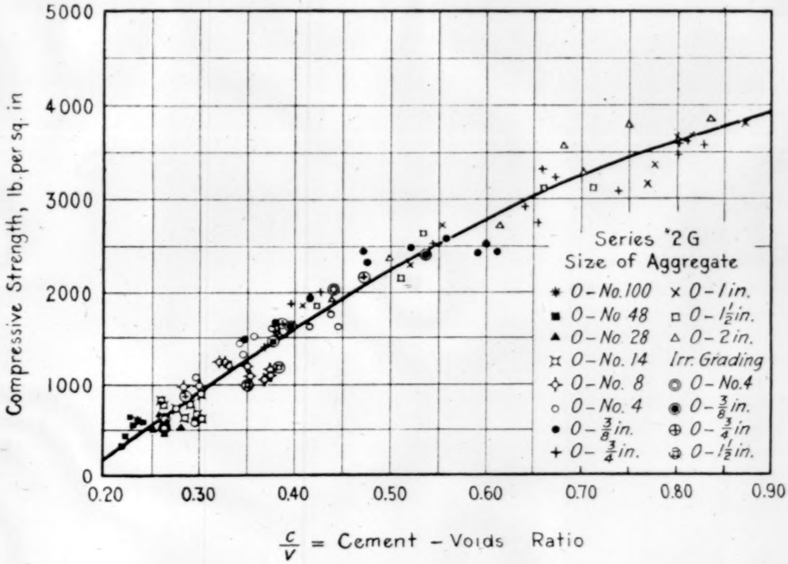

FIG. 3.—Relation between Compressive Strength of Concrete and Cement-Voids Ratio.—Series 2 G.

the coarse mixtures of each size, or in terms of the absolute volume of the cement from 0.08 to 0.10 cu. ft. of cement per cubic foot of concrete. The concrete was all of a normal consistency, giving 0 to ¾ in. of slump for all the mixtures for which the slump test was found applicable and the same apparent degree of wetness for the very coarse mixtures. The results of all the very coarse mixtures are included in the points in Fig. 1—those in which the mortar part of the mixture does not fill the voids in the coarse aggregate and which are of less strength than the mixtures producing maximum density.

A plotted point represents the average of three or four test specimens. It is to be noted that for a 1 : 5 concrete having 0.10 voids, the strength at 28 days was 4000 lb. per sq. in.; for 0.35 voids the strength was only 500 lb. per sq. in.

In Fig. 2 the same tests have been plotted in terms of the ratio of the voids in the concrete to the absolute volume of the cement used in a unit of volume of concrete.

In Fig. 3 the same tests have been plotted in terms of the ratio of the absolute volume of cement per unit of volume of concrete, *c*, to the voids in this volume of concrete, *v*.

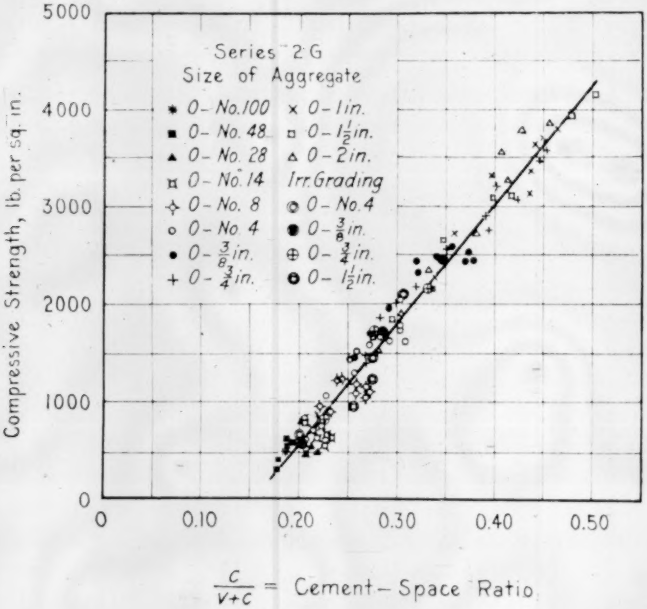

FIG. 4.—Relation between Compressive Strength of Concrete and Cement-Space Ratio.—Series 2 G.

In Fig. 4 the same tests have been plotted in terms of the ratio of the absolute volume of the cement, *c*, in a unit of volume of concrete to the space around and about the particles of the aggregate (sum of the voids and the absolute volume of the cement, $v+c$). This ratio gives the proportion of the space around and about the particles of the aggregate that is occupied by the cement and through which it is expected to act or be effective, and represents in a way the dilution of the cementing material.

Equations have been derived which represent fairly well the average of the plotted points in Figs. 1 to 4, but they are withheld pending the completion of another set of tests.

Consideration has been given to data of tests in other laboratories. So far as found, the data show a close relation between strength on the one hand and amount of cement and voids on the other. The tests examined include a variety of gradations of aggregate and a number of mixes and consistencies. The belt of points is similar to those found in Figs. 1 to 4, except that the diagrams have a more pronounced trend toward the origin at the lower strengths than Figs. 3 and 4. Withey[1] has plotted the data from Technologic Paper No. 58, by Wig, Williams, and Gates. Taylor and Thompson[2] give a diagram of Feret's formula for strength of mortars, which involves the cement-space ratio with a parabolic form of equation. The relation between cement, voids, and strength has been recognized for many years.

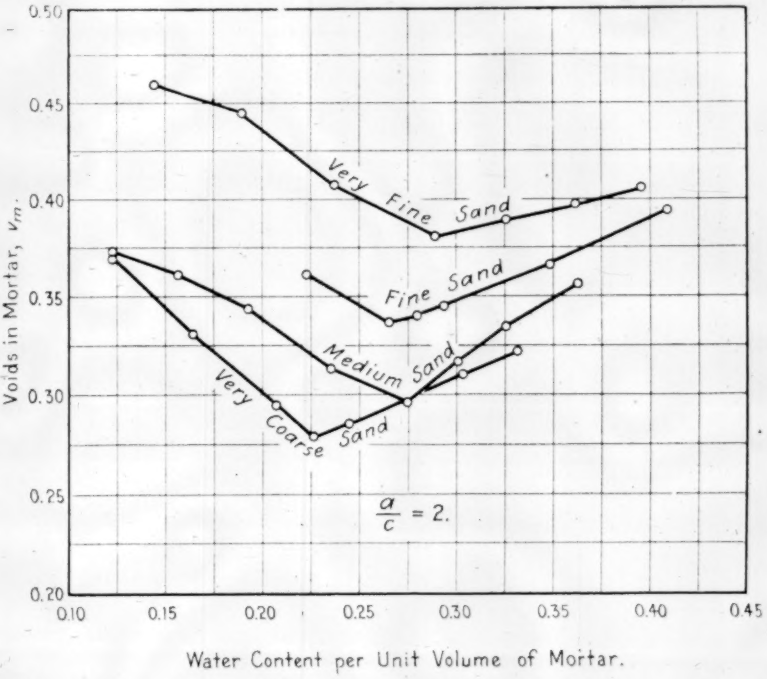

FIG. 5.—Relation of Voids in Mortars to Water Content for $\frac{a}{c} = 2$.

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[1] Johnson's Materials of Engineering, Fifth Edition, p. 464.

[2] Taylor and Thompson's Concrete Plain and Reinforced, Third Edition, p. 154.

VOIDS IN MORTARS.

Tests of mortars show that, for any given proportion of cement to fine aggregate, the voids in the mortar vary with changes in the volume of mixing water used. The value of the voids and their change with additions of water will depend upon the gradation of the fine aggregate, each aggregate having its own individuality. Fig. 5 shows the voids in mortars made with four typical sands—very fine, fine, medium and very coarse—for a ratio of fine aggregate to cement by absolute volumes, $\frac{a}{c}$, equal to 2. The water content is given in terms of the volume of the mortar; for example, 0.25 cu. ft. of water per cubic foot of mortar. For each of these sands, with additions of water the voids decrease to a minimum and then increase. The point of minimum voids (minimum volume of mortar) is definite and readily fixed; it is here termed the point of basic mortar voids, and the amount of water used per unit of volume of mortar is termed the basic water content. The water content in wetter mixes may be expressed in terms of the basic water content; a 1.30 basic water content would mean that the amount of water used per unit of

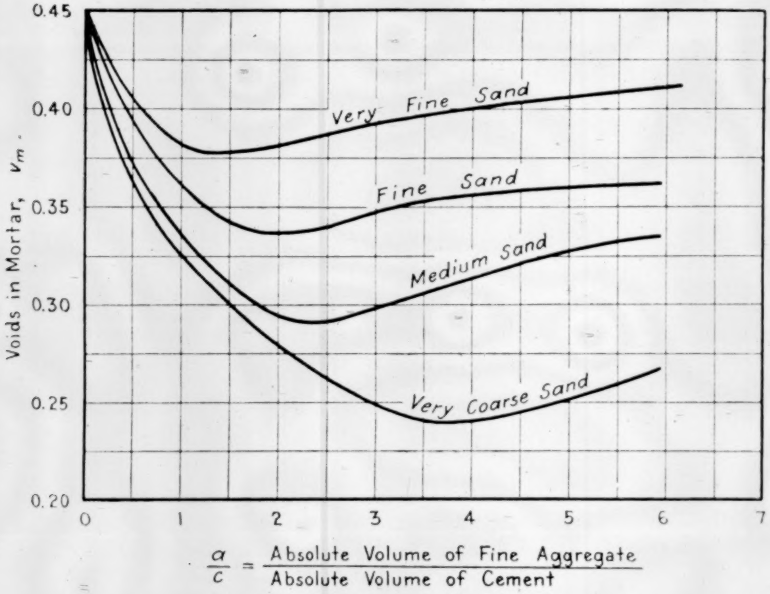

FIG. 6.—Characteristic Mortar Voids Curves at Basic Water Content.

volume of the resulting mortar is 1.30 times that water content per unit of volume of mortar which gives the minimum volume of mortar—the swelling of the mortar through the addition of water thus being taken account of. It will be noted in Fig. 5 that fine sand gives higher mortar voids than coarse and that the basic water content also differs. Mortars at basic water content are fairly near to what is usually considered normal consistency, or a little dryer.

By making the mortar-voids test for several mixes (several values of $\frac{a}{c}$), enough points may be determined to give the relation between voids in mortar and values of $\frac{a}{c}$ for the given fine aggregate. The value of the voids at minimum mortar volume (basic water content) has been taken from Fig. 5 and from similar diagrams for other mixes, and several such points were used in Fig. 6 for each of the four sands, giving what is termed the characteristic mortar voids curve at basic water content. In Fig. 7 characteristic mortar curves for the coarse and the fine sand are given at three water contents, the data having been taken from Fig. 5 and others like it.

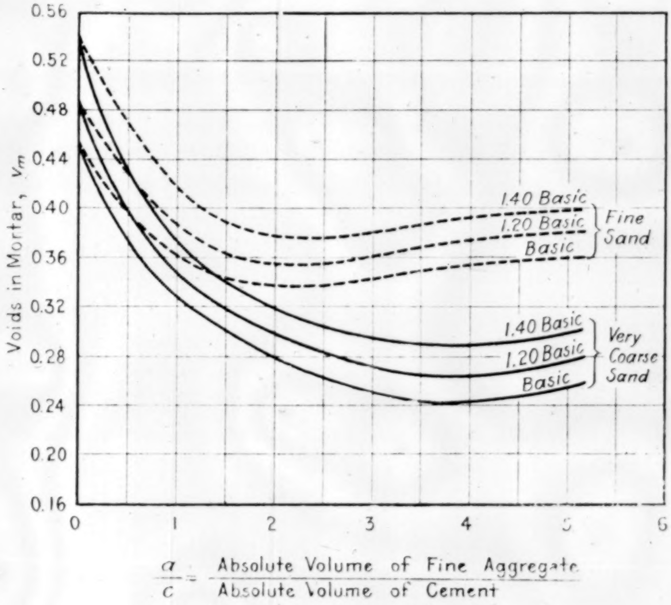

FIG. 7.—Characteristic Mortar Voids Curves at Three Water Contents.

Several characteristics of such curves may be noted. For a given water content the curves for different sands converge to a single point at the left, which represents the voids in neat cement at the given consistency. Two sands may not be expected to have the point of minimum voids at the same mix. The characteristic curve of a coarse sand generally shows a rapid increase in voids as the richness of the mix is increased from $\frac{a}{c}=2$; this property of a coarse sand will be found to tend to limit the advantages of the coarse sand in rich concrete mixes or where a well graded coarse aggregate is available. The relative increase in voids with the addition of more water is less for a fine sand than for a coarse sand.

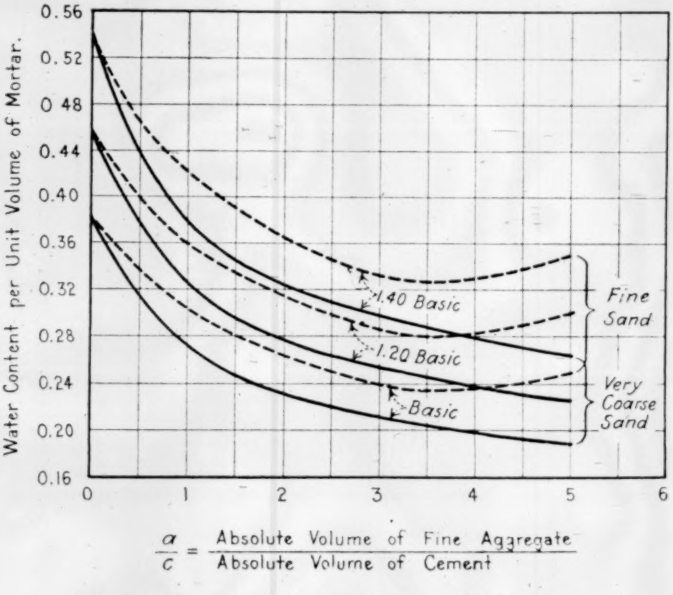

FIG. 8.—Water Content for Mortars with Two Sands.

For a given fine aggregate, the water content required for a unit of volume of mortar may be taken for a number of mixes from curves such as those shown in Fig. 5 and then plotted to make a diagram such as that in Fig. 8. The three curves for each sand indicate the water content required for a unit of volume of mortar for the three conditions, 1.00 basic water content, 1.20 basic water content, and 1.40 basic water content. This water content curve may be made up at the same time that the characteristic mortar curve of Fig. 7 is prepared. The values take into account the bulking of the mortar with the addition of water. The curves in Fig. 8 bring out the variation in water content for different mixes and different sands.

ANALYTICAL TREATMENT.

Knowing the void properties of the mortar the application to the concrete mixture may be made by analytical considerations. The following notation will be used:

a = absolute volume of fine aggregate in a unit of volume of freshly placed concrete;

b = absolute volume of coarse aggregate in a unit of volume of freshly placed concrete;

c = absolute volume of cement in a unit of volume of freshly placed concrete;

d = density or solidity ratio of the freshly placed concrete;

v_m = voids (air and water) in a unit of volume of the mortar or mixture of cement, fine aggregate and water as it exists in the concrete.

v = voids in a unit of volume of the concrete. This, of course, will be equal to $1-d$.

It is evident that

$$a + b + c = d = 1 - v \qquad (1)$$

Since the mortar and the coarse aggregate together make up the unit of volume, it is also evident that

$$\frac{c + a}{1 - v_m} + b = 1 \qquad (2)$$

A third equation derived from Eqs. 1 and 2 will be found useful:

$$v = v_m\,(1 - b), \text{or } b = 1 - \frac{v}{v_m} \qquad (3)$$

These equations give the relations necessary for determining the density of concrete; they may be used to check one another. It may be necessary to assume tentative values of one or more of the variables, and then modify the values so that Eqs. 1 and 2 will be consistent with each other. The characteristic mortar voids curve for the fine aggregate to be used, should be known in advance, though approximate values may be sufficient for certain purposes. Some of the conditions or cases to which the analysis may be made to apply are: a given value of c and a specified ratio of a to c; a specified ratio of b to a; specified values of b and c; and a specified value of $\frac{v}{c}$. In the examples which follow the value of v_m used is understood to have been taken from the characteristic curve of the particular fine aggregate that is to be used and for the ratio of a to c of the mortar mix, that curve being used which corresponds to the water content ratio giving the desired consistency. In case the ratio $\frac{a}{c}$ is not known at the start a tentative value may be taken and a second calculation made with a revised value of v_m.

Case I. Given c and its ratio to a. To find d and the strength of the Concrete.—

Assume $c = 0.1$ and $a = 0.25$. This c corresponds closely to a 1 : 5 concrete mix and a to a not uncommon relation between cement and sand. Consider that for $\frac{a}{c} = 2.5$ the value of v_m is known to be 0.30.

$$\text{Then } \frac{0.1 + 0.25}{0.70} + b = 1 \therefore b = 0.50.$$

$$0.25 + 0.50 + 0.1 = d = 0.85.$$

The ratio $\frac{v}{c}$, then, is $\frac{0.15}{0.10} = 1.5$, and from a diagram such as Fig. 2, the strength of the concrete may be expected to be, say, about 3000 lb. per sq. in.

Case II. Given c and $\frac{b}{a}$. To Find a, b, and d.—

Assume $c = 0.1$, $\frac{b}{a} = 2$, and $v_m = 0.30$

$$\text{Then } \frac{0.1 + a}{0.70} + 2a = 1 \therefore a = 0.25,\ b = 0.50, \text{ and } d = 0.85.$$

Consider that it is found from the characteristic curve of the fine aggregate used that for the ratio $\frac{a}{c}$ given by these values v_m is found to be 0.26 instead of 0.30. Rewriting Eq. 2,

$$\frac{0.1 + a}{0.74} + 2a = 1 \therefore a = 0.26,\ b = 0.52, \text{ and } d = 0.88.$$

For $\frac{v}{c} = \frac{0.12}{0.10} = 1.2$, the estimated strength for the conditions of the data of Fig. 2 is 3500 lb. per sq. in.

For a fine sand with $v_m = 0.40$ the values become

$$\frac{0.1 + a}{0.60} + 2a = 1 \therefore a = 0.23 \text{ and } b = 0.45$$

$0.23 + 0.45 + 0.1 = 0.78 = d$. For $\frac{v}{c} = \frac{0.22}{0.10} = 2.2$, the strength in Fig. 2 is 1800 lb. per sq. in.

Case III. Given b and c. To find a and d.—

Assume $b = 0.55$ and $c = 0.1$.

Then $\frac{0.1 + a}{0.70} + 0.55 = 1 \therefore a = 0.215$
and $0.215 + 0.55 + 0.1 = 0.865 = d$. For $\frac{v}{c} = \frac{0.135}{0.10} = 1.35$, the strength in Fig. 2 is 3200 lb. per sq. in.

The value of b here assumed may be beyond the limit which gives easy working conditions in placing the concrete; this matter will be discussed further on.

Case IV. Given $\frac{v}{c}$ *or* $\frac{c}{v + c}$. *To find a, b and c.*—

Assume $\frac{v}{c} = 1.0$ or $\frac{c}{v + c} = \frac{1}{2}$, this ratio being expected to give a concrete of a certain compressive strength. Consider as a preliminary or trial value that the sand gives $v_m = 0.35$.

From Eq. 1, $a + b + c = 1 - c$ and from Eq. 2, $\frac{c + a}{0.65} + b = 1$.

If v'_b (the voids in the coarse aggregate) is 0.4, the limiting value of b will be somewhat less than 0.6, say 0.55. This value will be favorable for securing concrete of high density, with fine sand, provided, of course, the resulting mortar mix does not give greater voids than the value assumed for the problem. Combining the two equations,

$$a + 0.55 + 2c = 1.54\,c + 1.54a + 0.55. \quad \therefore a = 0.85\,c.$$

Substituting in Eq. 2, $c = 0.158$ and $a = 0.134$.
From Eq. 1, $0.134 + 0.55 + 0.158 = 0.842 = d$.

If the mortar voids for the $\frac{a}{c}$ now found do not agree with the value 0.35 assumed, a new calculation may be made with a new value.

If it is thought that $b = 0.55$ will not give a sufficiently mobile mix, a smaller value may be chosen.

Case V. To Find the Amount of Cement Required with Different Fine Aggregates.—

Compare the amount of cement needed to produce a concrete estimated to have a strength of 2500 lb. per sq. in. at 28 days when the fine sand and the coarse sand of Fig. 7 are used. From a diagram such as Fig. 2 consider that $\frac{v}{c} = 1.7$ will give this strength. Consider further that 1.20 basic water content is to be used and that the size and gradation of the coarse aggregate is such that a value of b as high as 0.5 may be used. Upon consulting Fig. 7, assume 0.30 as a tentative value of v_m for the coarse sand and 0.37 for the fine. Then Eq. 1 becomes $a + 0.5 + c = 1 - 1.7\,c$. For the coarse sand it is found that $c = 0.088$ and $a = 0.262$. For the fine sand, $c = 0.109$; $a = 0.206$. Revising the calculations by using the voids found in Fig. 7 for the $\frac{a}{c}$ of these tentative results, the values become

For the coarse sand, $c = 0.081$; $a = 0.287$,
For the fine sand, $c = 0.103$; $a = 0.203$.

Case VI. Given the Water Content Curve for a Mortar with a Given Fine Aggregate. To Find the Water Content for the Concrete.—

When the values of a, b, and c for a concrete are known, and also the water content curve of mortars made with the given fine aggregate, the water content for the mortar may be found by taking from the curve for the desired consistency the value corresponding to $\frac{a}{c}$. The water content for the concrete may then be obtained by multiplying this value by the proportional space occupied by the mortar in the concrete, which is given by the expression $\frac{a + c}{1 - v_m}$, or its equivalent, $1 - b$. Thus, for the example in Case V, when $a = 0.287$, $c = 0.81$, and $\frac{a}{c} = 3.5$, the water content ratio for 1.20 basic water content from Fig. 8 is 0.25, and from Fig. 7, v_m is 0.27, $\frac{a + c}{1 - v_m} = 0.5$. The latter quantity is more readily found by the use of $1 - b$. Then the water required for a cubic foot of concrete of this mix at 1.20 basic water content is 0.125 cu. ft. This does not include allowance for absorption, etc.

Case VII. To Find the Effect of an Increase in Amount of Mixing Water upon the Density of the Concrete.—

Consider the coarse sand of Fig. 7. Use $c = 0.1$ and $\frac{b}{a} = 1\frac{1}{2}$. By the use of Eqs. 1 and 2 it will be found that for 1.00 basic water content, $d = 0.87$, for 1.20 basic water content, $d = 0.85$, and for 1.40 basic water content, $d = 0.83$.

For the fine sand of Fig. 7, the corresponding values of d are 0.80, 0.79, and 0.78.

MORTAR VOIDS TEST DATA.

Tests to determine mortar voids and the voids and strength of the corresponding concrete test specimens have been carried on in the Laboratory of Applied Mechanics of the University of Illinois. About thirty fine aggregates, including artificial mixtures, have been used. They include a variety of material. The results of the compression tests are not yet available. To show the variety and the individuality of the fine aggregates, the characteristic mortar voids curves of a number of these fine aggregates have been plotted in Fig. 9; these are given for minimum mortar volume or basic water content. The nature of the fine aggregates and the location or source of the supply are given in Table I, as well as the specific gravity, fineness modulus and surface modulus of the sample. Table II gives the sieve analysis of these fine aggregates, the sieves used being Tyler standard sieves. It should be noted that in the concrete test specimens proportioned

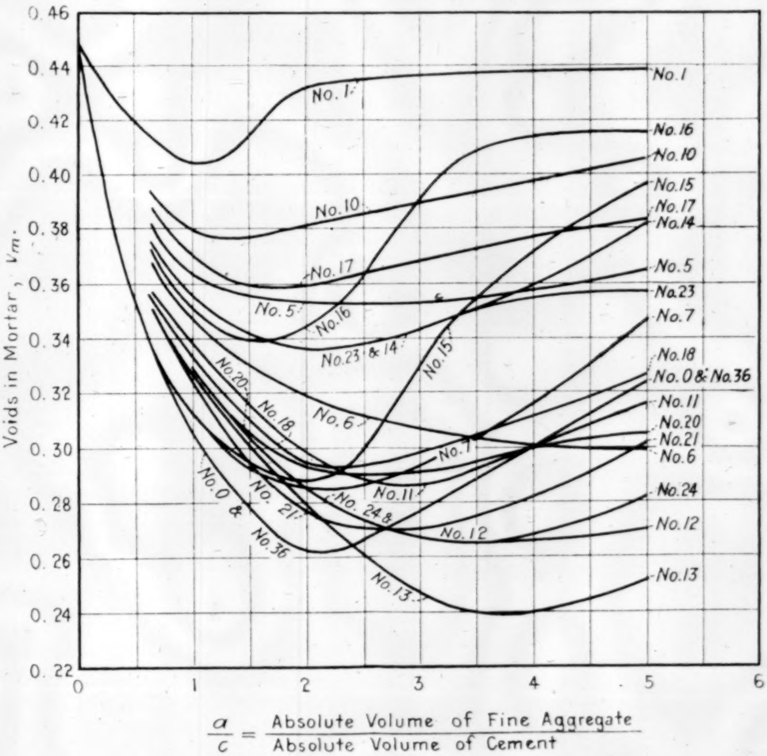

FIG. 9.—Characteristic Mortar Voids Curves for a Variety of Fine Aggregates.

and made up from the data of voids of these characteristic mortar curves and by the analytical methods already described, the voids of the specimens checked fairly closely with the predetermined values.

OBSERVATIONS.

A study of the analytical and experimental relations given in the preceding pages will lead to a number of observations, both old and new.

Generally speaking, the greater the value of *b* (the absolute volume of the coarse aggregate), the greater the density of the concrete (as is shown by Eq. 3), up to the point where the voids in the coarse aggregate are not filled by the mortar. Further, the better the grading of the coarse aggregate, the less its voids and the greater the maximum value of *b* that can be used in a concrete. For the tests in Series 2G already referred to, well graded gravel was used, and the greatest density and greatest strength for $\frac{1}{4}$–1-in. coarse aggregate were obtained with $b = 0.59$; for $\frac{1}{4}$–$1\frac{1}{2}$-in., with $b = 0.65$; for $\frac{1}{4}$–2-in., with $b = 0.63$—larger values of *b* resulted in greater voids and smaller strength. The highest density obtained was 0.90. These high values of *b* give a very harsh coarse mix, not easily worked and not applicable in concrete work except under unusual conditions of placing and tamping. There is, of course, some lack of adjustment through the larger particles of the mortar getting between the particles of the coarser aggregate (a wedging action it is sometimes called), and the voids in the concrete may even be thereby increased somewhat over the analytical values.

TABLE I.—FINE AGGREGATES OF FIG. 9.

No.	Description.	Specific Gravity.	Fineness Modulus.	Surface Modulus.
0	Ottawa standard sand	2.65	2.99	12.6
1	Sand from Joliet, Ill., screened through fine sieve	2.76	0.92	60.8
5	Sand from shore of Lake Michigan	2.64	1.40	40.2
6	Limestone screenings from Milwaukee, Wis	2.76	2.40	37.0
7	Chats from Joplin, Mo	2.60	3.80	13.2
10	Dune sand from Gary, Ind	2.68	1.00	51.6
11	Crushed slag from Chicago, Ill	2.70	4.11	12.8
12	Crushed granite from Berlin, Wis	2.61	3.41	23.5
13	Platte River "gravel" from Fremont, Neb	2.63	3.23	19.9
14	Glass sand from Mapleton, Pa	2.64	1.83	33.4
15	Crushed slag from Lorain, Ohio	2.64	3.70	17.9
16	Granulated slag from Buffington, Ind	2.51	2.69	22.7
17	Sea sand from Atlantic City, N. J	2.75	0.96	53.4
18	Sand from San Diego, Cal	2.71	3.50	13.7
20	Washed sand from Elgin, Ill	2.72	2.81	20.2
21	Sand from Medicine Hat, Canada	2.66	3.16	15.1
23	Sand from Greenup, Ill	2.63	1.41	41.6
24	Sand from Attica, Ind	2.69	3.34	16.6
36	Artificially graded sand between No. 28 to 4 sieves	2.69	3.70	8.7

For these reasons there must be a limiting value of the bulk of the coarse aggregate that may be put into a unit of volume of concrete; this may be 75 to 90 per cent of the volume of the resulting concrete, according to the gradation and shape of the coarse particles and the method of placing the concrete. A very well graded gravel coarse aggregate may have 0.35 voids and a density or solidity ratio of 0.65. If the requisite mobility of the concrete may be obtained when the bulk of the coarse aggregate is 90 per cent of the volume of the concrete, the upper limit of *b* for this aggregate would then be 0.59. For an aggregate of fairly uniform size the voids may be 0.45 and the density 0.55; $b = 0.51$ would be the corresponding upper limit for this. A still smaller amount of the coarse aggregate will give a more easily worked concrete; the need for mobility or workability will influence the choice of the limiting value of *b*, the limit thus depending upon the nature of the work.

TABLE II.—SIEVE ANALYSIS OF FINE AGGREGATES.

No.	Percentage by Weight Passing Each Sieve.					
	100	48	28	14	8	4
0	0	0	1	100	..	..
1	34	74	99	100	..	..
5	1	60	99	100	..	..
6	23	37	52	67	84	98
7	3	9	20	32	57	100
10	6	95	99	100	..	..
11	5	9	16	25	45	89
12	15	21	28	39	61	96
13	3	19	42	57	72	88
14	3	32	93	99	100	..
15	9	15	24	34	55	93
16	7	15	37	76	98	99
17	9	95	100	..	..	..
18	1	7	24	48	75	94
20	2	12	51	71	86	98
21	1	5	32	61	79	92
23	7	54	99	100	..	..
24	4	10	25	51	78	97
36	0	0	0	50	80	100

Tests to determine just what the limit of *b* should be for any given aggregate and any given working condition may readily be made. Well rounded pebbles will give a higher allowable value than elongated ones. The limit for broken stone may be expected to be lower than for gravel, the difference depending upon the angularity of the pieces. From this upper limit the value of *b* may, of course, range down to nothing. When the value of *b* used is less than the upper limit, differences in the grading of the coarse aggregate, of course, will not result in any change in the density of the concrete, provided the absolute volume of the coarse aggregate remains the same, and a coarse aggregate of uniform size will give the same density as one that is well graded.

For a given value of b the volume of the mortar given by Eq. 2 is $1 - b$. The value of a (the absolute volume of the fine aggregate) that fits in with a given value of b will depend upon the absolute volume of the cement c and upon the mortar voids v_m. In general, the finer the sand the greater the mortar voids and the less the volume of the fine aggregate that would be used. It will be found, however, that the extent of the difference will depend upon the nature and shape of the characteristic mortar voids curve.

In considering the effect of the shape and position of the characteristic mortar voids curve for different fine aggregates, shown in Fig. 9, it is well to note that the values of $\frac{a}{c}$ most commonly present in the usual concrete mixtures range from 1 to 5, though values outside of these limits may be encountered. It should be borne in mind, too, that both the richer mix and the mixture with a high value of b tend toward the lower values of this range, and that the leaner mixes and the lower values of b run toward the larger values of $\frac{a}{c}$. It may be noted also that the mix ordinarily specified for use in comparing strengths of mortars made with a given sand and with standard Ottawa sand is 1 : 3 by weight, which corresponds closely with $\frac{a}{c} = 3.5$.

The various fine aggregates of Fig. 9 show marked individuality. Minimum voids occur at different values of $\frac{a}{c}$, from 1 to 5. Some curves, like No. 24, show small voids between $\frac{a}{c} = 2$ and $\frac{a}{c} = 5$. In others, like No. 15, the voids increase rapidly on either side of the minimum. Sand No. 10 (a very fine sand) has its minimum well to the left; the most favorable use of this sand is with a large proportion of coarse aggregate and a rich mix. Thus, for $c = 0.15$, $b = 0.55$, and $v_m = 0.38$, the values calculated by Eqs. 1 and 2 for No. 10 are $a = 0.13$ and $d = 0.83$. For the same values of c and b, No. 6 gives $v_m = 0.35$, $a = 0.14$ and $d = 0.84$, and the sand of lowest minimum voids (No. 13) gives $v_m = 0.33$, $a = 0.15$ and $d = 0.85$. For these proportions little difference may be expected in the strength of the three concretes.

It may be noted that with sand No. 13 and this rich mix ($c = 0.15$) the density of the concrete is not greatly changed by a reduction in the amount of coarse aggregate; with $b = 0.38$, $d = 0.83$, and with even a very small amount of coarse aggregate ($b = 0.12$) and $a = 0.52$ the density is 0.79. This sand shows its superiority, however, with the leaner mixes—$c = 0.07$, $a = 0.27$ and $b = 0.55$ indicate a density 0.89. For a medium richness, too, it will give excellent results with a medium proportion of coarse aggregate without regard to the grading of the coarse aggregate. For mixes similar to that just given, No. 6 will give a density of 0.86 and No. 10 of 0.82. For smaller values of b the divergence is much greater.

A sand like No. 24 is well fitted for a wide range of mixtures. Others, like Ottawa standard sand and No. 36, are most suitable for rich mixes. No. 13 shows up well with lean mixes and is not particularly advantageous when used with high values of b.

The data of the tests show that at minimum volume (basic water content) the voids in the mortar are not entirely filled with water, the proportion varying with the nature of the fine aggregate and the richness of the mix and ranging from 60 to 90 per cent or even somewhat more. Seventy-five to ninety per cent are common values. The leaner mixes generally have more air voids than mixes near that which gives the lowest percentage of voids; richer mixes than the latter tend toward the value for neat cement paste, about 15 per cent of the total voids.

When a larger amount of mixing water than that giving minimum mortar volume is used, the proportion of air voids is decreased. A concrete having 30 to 40 per cent more mixing water than basic water content may have the voids practically filled with water. This 30 or 40-per-cent additional water content is accompanied by an increase in voids in the concrete of generally only 10 to 20 per cent of their value, though some of the sands gave a larger increase than this. For the wetter mixes the water content is a fairly good measure of the voids in concrete.

Minimum voids and basic water content give a rather dry mix, but it is evidently close to the point of maximum strength of concrete. Expressing the desired water content as a coefficient times the basic water content would appear to be a definite and reasonable method. A specific coefficient, however, when used with different values of b, or with fine aggregate of widely different quality, may not be expected to give the same mobility or workability. Both the slump test and the flow table give different results for a mixture high in coarse aggregate and for one low in coarse material, even though the degree of wetness of the material is apparently the same. The mobility of the concrete is dependent upon the amount of coarse materials as well as upon the wetness of the mix.

A POSSIBLE METHOD OF SPECIFYING THE QUALITY OF FINE AGGREGATE.

The ease of making the mortar void test and the definiteness in the location of the point of minimum volume and in the increase of voids with the addition of water suggests the value of this method as a means of rating fine aggregates so far as the effect of the size of particles is concerned. There is such a variety of fine aggregate available in different parts of the country, very divergent in character, and the needs in concrete construction are so divergent that difficulty has been found in specifying a gradation or a size of particles that is generally acceptable. The test of a sand to determine the mortar voids, with characteristic mortar curves at several water contents, such as are shown in Fig. 7, will enable a study to be made of the concrete-making properties of the sand, and it may be rated or judged from these curves. In making up specifications for fine aggregate, generally only the voids at minimum mortar volume for a definite richness of mix need be considered. The requirement may take one of several forms:

1. A maximum limit of voids for a given mix may be specified, say for a ratio $\frac{a}{c}$ of $2\frac{1}{2}$. The value of this specified maximum may then be fixed for a given locality or a given purpose, according to the materials available.

2. A maximum limit of voids for a given mix may be specified for use with the specified proportion of cement to aggregate; a fine aggregate with mortar voids exceeding this, up to a given limit, may be used, provided the amount of cement per unit of volume of concrete is increased sufficiently to give a concrete coming within a cement voids ratio which would be specified.

3. The limit of voids may be set quite high and the requirement made that for the fine aggregate used the amount of cement and the proportions of the cement, fine and coarse aggregate, and water shall be such that the cement-voids ratio of the resulting concrete shall come within a specified limit.

It would appear that all three forms would be useful; one might be preferable under some circumstances and another under others.

If the general quality of the fine aggregate in other directions than size and gradation were not known, as in a sand which may be weak in structure, or which may have a poor surface for adhesion, or in a new and untried light aggregate, a strength test should be made in such way as to give a comparison with mortar or concrete made with a fine aggregate of known quality. For such a test the two fine aggregates should have the same gradation of particles.

LABORATORY AND FIELD METHODS.

The laboratory procedure in making the tests herein reported did not differ materially from ordinary practice. The method of test to determine the relation between water content and volume of mortar, in such a way as to determine the characteristic mortar voids curves and the water content curves for mortars made with a given fine aggregate, are given in Appendix I, as well as the method used for finding specific gravity of the aggregate. An operator was usually able to make a check determination within $\frac{1}{4}$ per cent, and the results for additions of water to the mortar themselves were checks upon the accuracy of the determinations preceding them. The error in determining specific gravity is more important, but with care it should be less than $\frac{1}{2}$ per cent; the results with two methods gave approximately identical results. The point of minimum volume and the basic water content are quite definitely determinable. It is convenient in making calculations to have the allowance for absorption by the aggregate included in the value of the specific gravity, and this plan should be followed whenever feasible. After making several tests with the same batch, the loss of water in the process will be found to affect the accuracy of the results. This trouble may be overcome by carrying one batch a little past the point of minimum volume and starting a second batch a little back of this point.

The observed voids in the concrete test specimens checked rather closely with the predetermined values obtained by calculation from the mortar curves. The average variation from the expected value for 60 sets of test specimens examined was less than 1 per cent of voids, the observed value most generally being above the calculated value. In some of the specimens with the larger values of b it was found that the mortar did not fill the voids throughout the specimen.

As the sum of the solids in the concrete test specimens was found most frequently to be less than unity, it may be considered advisable to modify Eq. 2 by making the second member of Eq. 2 say, 0.995 or 0.99 instead of 1, or perhaps a better plan would be instead to give a coefficient of say, 1.01 or 1.02 to b in the first member of the equation. Such a modification would provide for increase in voids due to the separation or wedging of the particles of the coarse aggregate by the mortar, something which is especially likely to be present when a large proportion of coarse aggregate is used. It was found also in making calculations with data of another laboratory that the sum of the mortar volume and that of the coarse aggregate seemed to be 0.99 or even less, though part of the difference may be due to difference in methods of making the tests. What is the best way of taking such conditions into account is a matter for further consideration.

It should be added that the work of weighing, mixing and making both the mortar specimens and the concrete specimens was done by laborers who had had no previous experience in laboratory testing or other work of a similar nature. The specific gravity tests were made by skilled observers. There would be little difficulty in making even this test in the field.

For field use, the absolute volumes that have been decided upon from the analytical consideration of the tests with the given aggregate may be converted into bulk or weight measurement. The weight or bulk determinations should be made with the aggregate in the condition of moisture and compactness that it will have when measured on the work. It will be convenient to use the bulk or weight of the fine and coarse aggregate corresponding to one bag of cement. Methods for making the conversion are outlined in Appendix II. Instead of the exact proportions found from calculations, values in round numbers which seem more convenient for measurement may be chosen if the calculations show that the resulting change in density is within allowable limits.

GENERAL COMMENTS.

With reference to the sieve analyses of the fine aggregates, it may be said that they do not bring out all the differences in the characteristics of the fine aggregates shown in Fig. 9; they of course show general differences in gradation. From physical considerations it seems evident that a sieve analysis, or a function derived therefrom, cannot be expected generally to measure or determine the voids in the concrete, because (1) a group of particles of about the same size near the upper or lower size, or at some intermediate size, may be sufficiently in excess of its proportionate amount of volume to interfere with the law of voids which may govern with regularly graded particles, (2) the sieve analysis does not take into account the bulking of the particles when wet, nor the difference in the amount of bulking for particles of different size, and (3) the sieve analysis for the reason given in (1) cannot take into account the changes in bulk due to a change in the amount of the cement used in the mix.

It follows then that while such devices as fineness modulus, surface modulus, and surface area may give a fairly satisfactory way of representing the voids function in material having certain regular gradations of size used with a certain proportion of cement and having certain degrees of bulking, they cannot represent at all generally the variety of differences in grading and bulking and the variety in the cement proportions that are found in the general run of aggregates and concrete mixtures.

The mortar voids test takes account of the factors which give uncertainty to the sieve analysis function. If the requirements for structural strength and surface adhesibility be otherwise guarded, it will enable new or untried materials to be judged. It is of interest in showing what range of mortar richness will produce best results and what conditions will permit the use of what may have been thought to be a poor aggregate. Doubtless further study and experience will develop many limitations and suggest modifications and standardization of methods. It is evident that for the condition of mortar not filling the voids in the coarse aggregate there must be a limit to the applicability of the voids-strength relation. The shrinkage of wet mixtures and rich mixtures must be taken into account in the measurement of voids. Only physical conditions are here considered and any difference in conditions that affects the chemical action of setting and hardening is a separate factor. In practical use the fine material of the coarse aggregate will have to be counted in with the fine aggregate, and the coarse material of the fine aggregate as part of the coarse aggregate. When using coarse aggregate of the smaller sizes it may be found desirable to use a screen smaller than $\frac{1}{4}$ in. as the limit between fine and coarse aggregate. The variations inherent in fabricated materials must be expected to affect the accuracy of the findings, as will the errors of measurement involved in the testing processes.

The proposed method suggests reasons for what have seemed to some to be anomalous results in tests of concretes. Assistance is given in judging of the effect of change in proportions and of change in materials. It gives promise of usefulness to the designer and user of concrete.

Acknowledgment.—For assistance in developing the methods of testing used, credit is due F. E. Richart, Research Associate in the Engineering Experiment Station of the University of Illinois; H. J. Gilkey, First Assistant, and R. L. Brown and M. C. Nichols, students in the Graduate School. Acknowledgment is also made to Prof. D. A. Abrams for furnishing a large variety of fine aggregates for use in the tests.

APPENDIX I.

TECHNIQUE OF THE MORTAR-VOIDS TEST.

By F. E. Richart.

The general scheme in the determination of mortar voids for a fine aggregate involves the study of the effect of richness of mix and of wetness of the mortar. Accordingly, several proportions of $\frac{a}{c}$ (ratio of absolute volume of fine aggregate to absolute volume of cement) must be used; values of $\frac{a}{c}$ equal to 1, 2, $3\frac{1}{2}$, and 5 will usually furnish sufficient data for the purpose. Each batch of materials is mixed with successive increments of water, passing from a very dry to a very wet mixture, and the voids are determined for each successive water content. Since the whole operation for a given batch of material need not take more than 20 to 30 minutes, the water lost by absorption and evaporation is not large, but it may need to be considered. For a more careful method, one batch may be carried a little past the point of minimum volume and a second batch started a little back of this point. This overlap will show the effect of absorption and evaporation. The test for four values of $\frac{a}{c}$ may be made in two to three hours by one operator and one recorder, and usually the recorder can calculate the data and plot curves from the results of the test within this time. The work of the operator may be done by an ordinary workman; with any operator a few days' experience in handling the mortar will generally result in increased uniformity and reliability of results. The usefulness of the mortar-voids test depends upon producing a degree of compactness in the mortar commensurate with that to be expected in concrete made with the same mortar.

In selecting samples of fine aggregate, particular care should be taken to secure representative samples. The aggregate should preferably have the same known moisture content as when it is used for making concrete, or if dry, allowance may be made for the moisture present when the concrete test specimen is made.

The apparatus needed for making a laboratory test are a mold or container, accurate balances or scales, burette for measuring water, mixing pan, small trowel and tamping rod. A 2 by 4-in. cylinder mold, made from seamless drawn tubing and provided with a solid bottom, has proven satisfactory for mortar tests. Comparative tests have shown no appreciable difference in accuracy between results from this mold and from a larger one. The 2 by 4-in. mold can well be used with light laboratory scales and other apparatus, and the following remarks refer to the use of this size of measuring unit. In using another size of mold, proportional quantities may be substituted which will result in a similar degree of accuracy in the results. The balances or scales used should give weights accurate to the nearest gram, and the burette for measuring water should have a capacity of 200 cc. and be graduated in 1-cc. divisions. The volume of the mold (approximately 200 cc.) may be found by use of the burette more accurately than by measuring it with calipers and scale. The mold should be weighed carefully, or its weight may be counterbalanced by a container filled with sand on the opposite arm of the balances.

In measuring out materials for a batch for a given value of $\frac{a}{c}$, it is convenient to use an even value of $a + c$ which is about equal to the volume of the mold. A value of 200 cc. provides some excess mortar for the 2 by 4-in. mold, and also simplifies calculations. Knowing a and c, the weights for use are found by multiplying a and c by the respective specific gravities of the two materials (and by 62.4 if English units of weight and measure are used).

After weighing out the sand and cement they should be mixed dry, then water of about 7 per cent of the weight of the dry materials may be added. This will usually be less than the amount of water required for minimum volume of mortar; fine sands and rich mixes will require more. The mortar is then mixed thoroughly with the trowel and placed in the mold in layers of about 1 in., tamping each layer firmly, but without too much pressure. For the dry mixes the flat ended wooden tamping rod, about $\frac{3}{4}$ in. square is essential, as a pointed rod will leave holes in the mortar instead of compacting it. When the mold has been filled the top is struck off neatly with the trowel, the outside of the mold wiped clean, and the known volume of mortar is weighed. A check reading is taken by emptying the material back into the pan, filling the mold and weighing again.

With the same batch of mortar, another increment of water is added, mixed thoroughly, and the weight of mortar in the mold is determined for this water content. The process is repeated with further increments of water, taking several values near the point of minimum voids and increasing the size of increment after this point is passed.

From the weight and volume of the mortar in the mold and the weights of the ingredients, the volume of the batch of mortar is calculated by simple proportion, assuming that the mortar in the mold is representative of the batch. The ratio of the absolute volume of sand and cement to the volume of the batch is equal to the density of the mortar, or to the complement of the voids. It may be noted that by making $a + c$ equal to the volume of the mold, the density of the mortar is equal to the ratio of the "weight of mortar in mold" to the "total weight of materials." A typical form of data sheet from a mortar-voids test is given below.

TABLE I.—MORTAR-VOIDS TEST.

Sand No. 41
$\frac{a}{c} = 2.0$
$a + c = 200$ cc.

Specific gravity of sand, 2.67
Specific gravity of cement, 3.10
Volume of mold, 204 cc.

Cement.		Sand.		Weight of Water, g.	Total Weight of Materials, g.	Weight of Mortar in Mold, g.	Volume of Batch, cc.	Density of Mortar.	r_m
Weight, g.	c	Weight, g.	a						
207	67	356	133	40	603	a 408 b 406	...	.....	.....
						Average 407	302	0.662	0.338

In the performance and use of the mortar-voids test it is necessary to know the specific gravity of the fine aggregate and cement. The method[1] usually specified for determining the specific gravity of cement using the graduated LeChatelier flask, may be used equally well for fine aggregate, provided, of course, that no particles are larger than the neck of flask. The aggregate when used in mortar or concrete will necessarily absorb some water during mixing. In order to allow for this increase in the weight of the particles of aggregate the scheme of determining the specific gravity of the aggregate after fifteen minutes' immersion in water may be used. It is felt that this will closely approximate the actual condition of the material in a mixture and should add to the accuracy of the void determinations. The amount of absorption during the fifteen minutes' immersion should also be determined for use in correcting the water content of the mortar. A method of determining the absorption is described in detail in a report[2] of Committee C-9 of the American Society for Testing Materials.

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[1] Standard Specifications and Tests for Portland Cement (C 9) of the American Society for Testing Materials, 1918 Book of A.S.T.M. Standards, p. 503.

[2] Report of Committee C-9, Appendix I, "Outline of Compression Tests of Concrete for Investigation of Properties of Concrete Mixtures," *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 294 (1920).

APPENDIX II.

BULK AND WEIGHT MEASUREMENT IN THE FIELD.

The absolute volumes of the ingredients were used in the analysis and in the tests. For field use these may readily be converted into bulk or weight measurement.

Let w_a, w_b, and w_c represent the weight per unit of volume (bulk measurement) of the fine aggregate, coarse aggregate, and cement, respectively, in the condition and with the compactness they will have as measured on the work. w_c is conventionally taken as 94 lb. per cu. ft. The unit weights of the fine aggregate may be easily determined.

Let v_a, v_b, and v_c represent the voids per unit of volume in the fine aggregate, coarse aggregate, and cement, respectively, in the condition in which they will be measured on the work. The conventional weight, 94 lb. per cu. ft. makes $v_c = 51$ per cent. If the specific gravity of the aggregate is known or the weight per cubic foot of the solid material, v_a and v_b may be found from w_a and w_b. The weight of a cubic foot of solid particles of cement may generally be taken as 193 lb., and 167 lb. per cu. ft. is quite a common value for the solids of gravel and sand.

Let V_a, V_b, and V_c represent the bulk of the fine aggregate, coarse aggregate, and cement, corresponding to a, b, and c, respectively, and let V'_a and V'_b represent the bulk of the fine and coarse aggregates in the mix corresponding to one cubic foot of cement (one bag).

Then

$$V_c = \frac{c}{1 - v_c} = 2.05c, \quad V_a = \frac{a}{1 - v_a}, \quad V_b = \frac{b}{1 - v_b},$$

$$V_c' = 1, \; V'_a = \frac{0.487\,a}{(1 - v_a)c}, \text{ and } V'_b = \frac{0.487\,b}{(1 - v_b)c}$$

For aggregate with solid matter weighing 167 lb. per cubic foot the last two equations become

$$V'_a = \frac{81.5a}{w_a c} \qquad \text{and } V'_b = \frac{81.5b}{w_b c}$$

If the aggregate is to be measured by weight, then the weights of the fine aggregate W'_a and coarse aggregate W'_b corresponding to one cubic foot of cement in the mix will be, for aggregate with solid matter weighing 167 lb. per cu. ft.,

$$W'_a = \frac{81.5a}{c} \qquad \text{and } W'_b = \frac{81.5b}{c}.$$

DISCUSSION.

Mr. Withey. MR. M. O. WITHEY (*presented in written form*).—The fundamental relations of the strength of concrete to the cement-voids and "cement-space" ratios have again been demonstrated by the results of Mr. Talbot's experiments. From these data and others, which have been previously reported, there can be little question regarding the truth of these laws, providing the consistency of the mix and the "surface-adhesibility" are maintained constant. I hope Mr. Talbot's proposed analytical methods for investigating and designing concrete mixes will be carefully considered by our Committee C-9 on Concrete and Concrete Aggregates. Although I have not had experience in using the proposed methods, yet there appears to be so much merit in them that I should be in favor of soliciting the cooperation of several laboratories for the purpose of performing a short series of tests to investigate the practicability and truth of the methods.

I am in some doubt concerning the accuracy of Eq. 2 in the paper. It appears to me that when the mortar and coarse aggregate are mixed together, the voids in the resulting concrete will not necessarily be equal to the voids in the mortar. However, from Mr. Talbot's experience with the method it appears that the error involved in Eq. 2 is very small.

Mr. Blair. MR. W. P. BLAIR.—I should like to ask Mr. Talbot, regardless of the sizes of the aggregates, if some variations may not be expected due to the absorptive qualities of the aggregates themselves.

Mr. Talbot. MR. A. N. TALBOT. I did not mention that feature, but of course, in this procedure, in any procedure that deals with the properties of concrete, it is necessary to take into account the amount of absorption of water by the aggregates during the time of making the specimen, at least, and perhaps beyond that, and in these tests an amount was allowed for which was found by experiment to be the proper amount for the absorption up to the time or about the time that the concrete would be mixed and in the mold. It is probably true that a material which does not absorb much water does not give quite as good adhesibility as one which does absorb some water during the time of setting. There may be a film of water there, I suppose, if we would speculate upon it, which will interfere with the adhesion, with the cement coming in direct contact with the grains. We made tests on these same sands for their "adhesibility," as we call it, by

Mr. Talbot. taking the same gradation of particles of Attica sand that were found in each of these other sands, and making up mortar cylinders with both. In general, there was close agreement, but in the case of standard Ottawa sand, for example, the strength was lower than it was with the Attica sand for the same gradation of particles. I believe it has been found that if certain kinds of particles of coarse aggregate are soaked so that they are fully saturated with water at the time the concrete is made, there results a decrease in strength, due, I suppose, to the fact that there is less favorable condition for adhesion between the particles and the cement.

Mr. Crum. MR. R. W. CRUM.—Mr. Talbot's paper proposes a method of determining the amount of cement to use with aggregates of different characteristics. This contribution is, therefore, extremely valuable, since information upon that phase of proportioning has been very slight. In certain localities in Iowa, sands are available which are excellent in every respect except in the grading, but we have hesitated to use them for lack of information as to proper methods of proportioning. We intend to study these materials by the methods outlined in the paper, and expect to be able to write specifications covering their use. Mr. Talbot demonstrates the principle that the strength of concrete varies with the voids-cement ratio. This principle has been proved a number of times and has recently been used in proportioning the mixtures for about $5,000,000 worth of concrete paving in Iowa. In these mixtures the ratio of sand to coarse aggregate varied from 40:60 to 70:30.

Mr. Hatt. MR. W. K. HATT.—At Purdue University we have been investigating plant-produced aggregates. Sand and gravel plants are of a permanent character, some of them built of reinforced concrete. These manufacturers have large beds of sand and pebbles mixed, which should be used economically and conserved wisely. If there is any economy in the production of these aggregates, it is finally reflected in the tax duplicate of the citizen. Our state specifications for roads hitherto have required arbitrary proportions; and as a basis for accepting the aggregate, the $\frac{1}{4}$-in. screen was specified. Now it so happens that our gravel beds do not run true to specification. Nature has placed about twice as much of what we call sand as pebbles, whereas the specifications require just the opposite. Around these plants there is sometimes a large pile of good coarse sand, almost as large as grits, from $\frac{1}{8}$ to $\frac{1}{4}$ in., which, except for local sale, is not used. We were interested to find out if there was not some way of using more of this coarse sand in the speicfications for aggregates. Some people advocated separating sand and pebbles on the $\frac{1}{8}$-in. screen instead of $\frac{1}{4}$-in. screen. It is too late

Mr. Hatt. now to change our formal basis of division. However, it leads to some error to consider a definite separating line between the fine and coarse aggregate in case of sands and gravels; we have to consider the whole thing.

In screening at the plants a certain amount of the so-called grits comes over with the coarse aggregate and lies with the latter. Heretofore we have only allowed 5 per cent of this coarse material which lies with the coarse aggregate to be received under the specifications.

In our tests we first took our plant-produced aggregates of the various sizings and mixed them together in concrete of various proportions, leaving out certain fractions, and overlapping others. The strength of the concrete made up of the several variations of fractions did not differ substantially.

The next problem was to make a series of concrete 1 : $1\frac{1}{2}$: 3, 1 : 2 : 4, 1 : 3 : 6, etc., allowing this tolerance material to lie in with the coarse aggregate up to 30 per cent. The results have been published in the 1921 proceedings of the American Concrete Institute and the October number of Public Roads show that we can allow 15 per cent of this coarse material to lie in with the coarse aggregate without substantially affecting the strength of the concrete. That means that the plant can run the screens a good deal faster and increase the production without affecting the concrete-making properties of the aggregate. There is a great saving of sand which otherwise may be wasted and also an increased production in the plant. It seems to me that as the business becomes established, as these plants become permanent and these producers wake up to the fact that there is a science in the bringing together of cement, water and aggregate to make concrete, we can come to plant-mixed aggregates.

It may be objected that the plants cannot deliver an aggregate of any specified tolerance, but apparently the tolerance may vary without affecting the strength or the amount of water necessary to produce the specified consistency in substantial amounts in the case of mixtures richer than 1 : 3 : 6.

Mr. Butterfield. MR. E. E. BUTTERFIELD.—I should like to supplement Mr. Hatt's remarks by stating that there are three complete mixing, washing and screening plants for the manufacture and sale of ready-mixed aggregate in the Metropolitan district of New York. The three plants together have, I believe, an average capacity of something like 400,000 cu. yd. of aggregate per year, and tests which we have made in the Borough of Queens show that the materials, as delivered and as are available in the market for concrete to be mixed under the usual conditions, one part of cement to five parts of aggregate, and of the same consistency of separately prepared 1:2:4 mixtures, show, generally, equally high and frequently higher strengths than separate 1:2:4 mixtures. It is important that we should have some form of specification for such commercial mixed aggregates, in view of the economy in handling as well as their accessibility and availability. A large part of the subway construction was carried on with some of these ready-mixed aggregates and they are now used largely in private building construction. Frequently the proportion of sand (or of material passing No. 4 mesh) has run up to 1:1 of the coarser than No. 4 mesh, because the Building Code of New York City requires either 1:2:4 concrete or a concrete of not less than 2000-lb. compressive strength, and it has been found possible to easily reach 2000 lb. with a mixture containing 1 part of sand to 1 part of gravel. For this and other reasons, the use of such mixtures has become rather extensive, and it seems to me to be good practice, although there are no public works' specifications, as far as I know, permitting the use of such materials. **Mr. Butterfield.**

I should like to say that it is refreshing to see a return to such simple basic considerations as volume and concentration in the proportioning of concrete, as contained in Mr. Talbot's paper. The relation of $\frac{c}{v + c}$ amounts practically to the concentration of cement in unit volume. The conditions are, of course, complicated by the presence of other materials and also by the physical or chemical state of the cement in suspension or solution. Without going into that at all, but taking strength of concrete as a function of the concentration of cement, there is a biological example for a similar relation in the case of another colloid, that is, the hemoglobin of the blood; the oxygen absorbed by hemoglobin in solution is practically the same as that absorbed by hemoglobin in suspension in the form of red blood corpuscles. It would be desirable if the theory of the strength of concrete could be reduced to secure such simple terms, although the probability seems somewhat remote at present.

Mr. Fisk. Mr. G. F. Fisk.—I should like to state in support of Mr. Talbot's paper, that in Buffalo we have been using this method for the last three years. The really practical way to make concrete is to take the materials as you find them and then make the concrete. I am speaking particularly now of paving. After the material is delivered on the street we take a sample both of the sand and stone or gravel, as it may be, and make a screen analysis of it; then, in accordance with Mr. Talbot's procedure, we determine the absolute volume of both the sand and stone, and use enough cement, enough mortar, to fill the

Mr. Fisk. voids, and we get very satisfactory results. We have in Buffalo what we call Niagara river gravel, which is a good, clean gravel, and particularly well graded. We do not pay any attention to the grading of it; we simply make the analysis, find the voids and fill those voids with cement. On a 1:8 mix we very seldom get below 1600 lb. and often times 2000 and 2100 lb. Our specifications read that the proportions of concrete materials shall be 1:8, the finer proportions to be regulated by the screen analysis of the material.

I might also say that we are doing something in Buffalo that is not done, so far as I know, in any other city. We have a good deal of re-paving. We take up the old concrete, which is natural-cement concrete, screen out the old sand, and use the old stone in the new concrete. To see it on the street you would not think it is worth anything. but when you determine the absolute volume and put in the right amount of mortar, you get just as good and sometimes better results than with gravel.

Mr. Crum. Mr. Crum.—As a matter of information I should like to say that the Concrete Road Specifications of the Iowa Highway Commission provide for the use of pit-run gravel. This specification has been approved by the Bureau of Public Roads, and 36 miles of pavement at a cost of $1,500,000 have been built in accordance therewith. Tests of 6 by 12-in. specimens made daily, sieve analysis of aggregate secured by washing the cement from a sample of the concrete each day, and observation for one year have confirmed us in the conclusion that these pavements are equivalent in every respect to those made with the common arbitrary mixes. The method of proportioning used was described before this Society at the 1919 meeting, in a paper entitled "Proportioning of Pit Run Gravel For Concrete."[1]

Mr. Talbot. Mr. Talbot.—I wish to show slides giving the results of the strength tests of concrete made with the thirty sands referred to in the paper. [The figures shown by the slides are not reproduced here. —Ed.] The amount of cement used corresponds approximately to 1:7, 1:5, and 1:3½ mixtures. The specimens were made up with two values of the coarse aggregate, one about as high as may be used and give a workable mix of concrete, and the other one-half or two-thirds of this value. The tests thus cover quite a variety of proportions. The tests shown in the slide were made at basic water content. Others made with a variety of water contents I am unable to show to-day. The equation of the curve given on the slide is

$$S = 27\,000\left(\frac{c}{v + c}\right)^{2.4}$$

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XIX, Part II, p. 458 (1919).

Mr. Talbot.

where S is the strength of the concrete in pounds per square inch, c the absolute volume of the cement, and v the voids in the concrete, as used in the paper. Perhaps a better equation would be

$$S = 32\,000\left(\frac{c}{v + c}\right)^{2.5}$$

It will be noted that the results of the tests generally lie close to the curve. The points for the limestone screenings, not shown on the slide, are quite a little above this curve, which I suppose is an indication that there is a chemical action which increases the strength of the concrete.

In the second slide I have selected the results of two sands which differ widely in characteristics. No. 24 is the Attica sand which has been used in our laboratory for fifteen years, a very good coarse concrete-making sand. No. 23, the Greenup sand, is a fine sand, as fine as is likely to be used for ordinary concrete-making purposes. It will be noted that the strengths fall fairly close to the curve, regardless of the difference in the sands and the variety of the mixtures. It may be said also that the tests of mortar cylinders agree fairly well with this curve, though for some reason our mortar specimens were not well made and did not give uniform results.

This slide shows for the mortars made up with the first eleven sands the proportion of the voids that are filled with water at basic water content—the remaining voids are air voids. Notice that for standard Ottawa sand in the rich mix about 90 per cent of the voids are filled with water, while for the lean mixtures only about 60 per cent are filled. For sand No. 1, a very fine sand, all mixes have about 80 per cent filled. The diagram illustrates the very great variation in the amount of air voids in mortars made up with different fine aggregates. I suppose that the shape of the particle has something to do with it, the nature of the surface as to capillarity, etc. If the water content is increased above the basic water content, a larger proportion of the voids is filled. The richer the mix, the more rapidly will they fill. In one sand, a 1.20 basic water content will have the voids practically filled, while with other sands a 1.40 basic water content will have air voids. The voids will increase with the addition of water, but not in proportion to the water added.

This slide represents the same two sands, Nos. 23 and 24, at different water contents. It will be noted that at the higher water content there still remains voids with the fine sand, especially in the lean mixes. This diagram also gives the volume of the cement per unit of volume of mortar. The curve for the cement-space ratio is a very useful line: from it the strength of the mixtures may be estimated.

Mr. Talbot. For water content higher than basic water content, the strength of the concrete is less than that indicated by the cement-space curve derived from tests at basic water content. For 1.20 basic water content this reduction in strength is, I judge, about 15 per cent. For 1.40 basic water content the reduction is still more. I hope someone will make a study of the physical action of the particle of cement and the film of water about the cement. Evidently there is a minimum film of water which gives the best strength; when that film is increased, regardless of whether the voids are filled with water or not, the strength is reduced. There evidently is not the same contact between the particles of cement. Regardless of this, this line of the cement-space relation is a very useful line in concrete design, and the effect of the additional water may be made a separate feature.

To make further comparison, the mortar tests from Technological Paper No. 58 of the Bureau of Standards, made at the St. Louis laboratory under Mr. Humphrey's direction, have been put on this slide. A great variety of fine aggregates from over the country differing widely in nature and quality were included in these tests. It will be noted that a large proportion of these points come within 500 lb. per sq. in. on either side of the mean line. Many of those below the band are marked in the paper as friable material, material that has low structural strength, and I presume that this characterization will explain most of the points below the belt. Several of those above the belt are limestones, and I presume that there must be some chemical action for other high points also. In this slide the strength of the mortars is plotted against the water-cement ratio. A general relation exists here, though there is a greater variation than in the preceding slide. The next slide gives the relation between strength of mortar and fineness modulus, and it indicates a general relation with considerable variation. If voids are indicative of strength, it would seem that there must be some relation between fineness modulus and voids; the next slide indicates that this connection exists in these tests. I have no slide to show the discrepancies in the strength — surface modulus relation, but the next slide shows that there is some relation between surface modulus and fineness modulus.

Other series of tests, made in different laboratories, give results corresponding closely to the cement-space curve shown on the preceding slides; quite as close, it seems to me, as may be expected from the variable material used in making concrete and with the chances for inaccuracies that exist in such tests. The connection between cement and voids and strength of concrete is not a new relation—it has been before the engineering public for a good while—but in recent

Mr. Talbot.

years the feeling has gone out that it is not true, or at least not of importance, and I am glad to bring out again that this relation does remain true after many years.

But my purpose is more than this. The paper goes beyond this. The analytical and experimental considerations of the void-cement ratio in mortars and their application to concrete brought out in the paper are believed to give useful means for designing and proportioning concrete mixtures, for comparing aggregates of different character, for specifying aggregates, for determining the amount of cement to be used, and for studying other relations. As I have said before, the relations will have to be modified for variations in water content or a relation between strengths for different water content established. I hope that the method will be studied and developed by those who are interested in concrete, and that, with further use and more knowledge of the principles and methods given in the paper, there will result an advance in our knowledge of concrete, and that the method will become useful for designing concrete mixtures, for studying concrete aggregate, and for specifying materials and mixtures.

A STUDY OF THE COMPOSITION OF BLAST-FURNACE SLAGS SUITABLE FOR CONCRETE AGGREGATE.

By L. G. Carmick.

In recent years the use of slags for the coarse aggregate in Portland-cement concrete has been increasing rapidly. It is a material that is available in immense quantities in many parts of the country, and it is highly desirable that it should be so used provided engineers can be assured of the permanency of concrete made from it.

There is, however, a certain degree of prejudice against slag in some quarters due to a fear of its disintegration after installation. It is, of course, well known that some blast-furnace slags slake or crumble to powder on cooling; in fact, great quantities of such powdered slag may be seen at many furnaces. It is generally believed that this is caused by the presence of calcium orthosilicate, which may exist in four distinct crystallin forms, stable between different temperature limits, and which increases in volume to the extent of about ten per cent in the inversion due to cooling. It was with the hope of adding something to our knowledge of the conditions under which slag disintegrates that the following work was undertaken.

The literature of slags is so voluminous and so widely scattered that no systematic search of it was undertaken. But it appeared, after consultation of such works and journals as were available, that the specific question of soundness had been rather neglected. At any rate nothing was found covering quite the same field as the present series of experiments, though the work of Rankin and Wright[1] and Field and Royster[2] was found of great value, though they refer to this question only incidentally.

About forty slags were collected from various blast furnaces, some of them sound and others entirely broken down. These were analyzed and their composition tabulated. But as the results did not seem to afford the information desired, it was decided to proceed in a different manner.

Commencing about August 1, 1920, seventy-five mixtures of pure materials have been made up and fused in the laboratory. The proportions were so arranged as to cover more or less the whole practical range of variation in the composition of blast-furnace slags. This number was divided almost evenly into two series, the first containing only silica, alumina and lime, and the second series being mixtures of silica, alumina and lime with a constant content of five per cent of magnesia. No attempt was made at a comprehensive investigation of the silica-alumina-lime system, as this has been done in painstaking detail by others. The experiments referred to here were made with the sole object of determining the range of composition within which a slag may be expected to crumble spontaneously.

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[1] "The Ternary System $CaO—Al_2O_3—SiO_2$," *American Journal of Science*, Vol. XXXIX, Jan., 1915.

[2] *Technical Paper No. 189*, Bureau of Mines, Dept. of the Interior.

The mixtures were packed into small graphite crucibles and fused in a gas furnace. A platinum-rhodium thermo-couple was introduced through a small hole in the side of the furnace and temperature readings made constantly during each heat. The thermo-couple was not, however, inside of the crucible and therefore the readings probably never gave the actual temperature of the melt, as there would be a considerable lag between the inside and outside of the crucible, both when the temperature was rising and when it was falling. The purpose of these temperature readings was to insure uniform cooling of the melts. When complete fusion had occurred and the mass had become fluid and quiescent, the temperature was reduced at the rate of 10° C. per minute until several hundred degrees below the fusion point of the mixture, after which it was permitted to cool to room temperature without regulation.

Great care was taken to secure the utmost similarity of conditions in all of the melts so that they might be justly comparable among themselves, even if it were found that they could not be fairly compared with actual slags. It may be stated here that nearly all of the melts were beautifully crystallin. There was, of course, a small amount of glass formed in every case, but the amount was less than that observed in most of the actual slags examined in this laboratory.

Each melt consisted of a button weighing about 20 g. and when cold they were easily detached from the graphite crucible by inverting and tapping on the table. The buttons were broken in half, if sound, and one piece preserved for observation. A careful analysis was made of each one. Invariably there was found a larger proportion of silica and alumina than had been put into the mixture, due no doubt to the absorption of argillaceous material from the walls of the crucible, and the amount thus taken up varied with the basicity of the mixture and with the temperature of fusion. It was therefore very difficult to prepare a slag of any predetermined composition, sometimes two or three trials being necessary before an approximation to a desired composition was obtained.

As the composition of each melt was ascertained, it was plotted on a diagram such as Fig. 1, the ordinate distances representing percentages of alumina and the abscissas percentages of silica. The lime or the sum of the lime and magnesia being a dependent variable, is not necessarily represented, being always 100 per cent less the sum of the silica and alumina. Thus, in Fig. 1 the point marked *a* represents silica, 31 per cent; alumina, 21.5 per cent; lime, 47.5 per cent; and the point marked *b* represents silica, 29.5 per cent; alumina, 18.5 per cent, and lime 52 per cent. Now if, as actually happened, the first of these remained sound and the second disintegrated spontaneously, it was assumed that the limit between soundness and unsoundness must pass between these points. In this manner, the whole field between silica 29 per cent and silica 43 per cent was investigated at intervals of from 1 to 2 per cent and a curve drawn between those which remained sound and those which crumbled spontaneously. This was done for a series containing only silica, alumina and lime, and also for a similar series containing (by analysis) about 4.5 per cent magnesia.

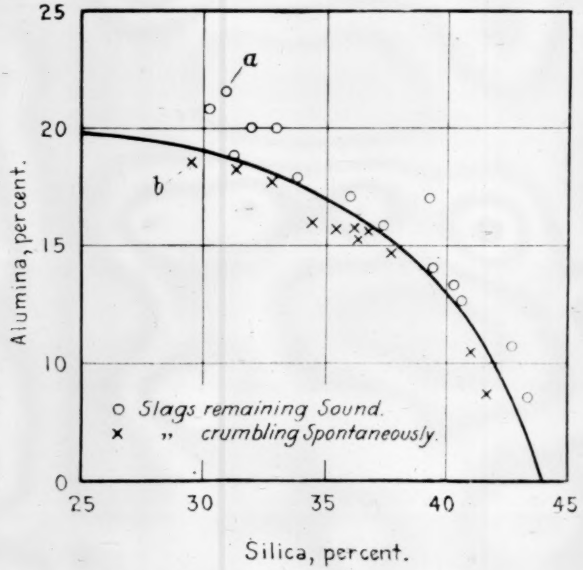

FIG. 1.—Diagram of Slag Compositions Showing Line of Demarcation Between Slags Remaining Sound and Those Crumbling Spontaneously.

In Fig. 1 the results for the first series are given, omitting only those which were so far from the limiting line that they were of no help in plotting it.

It had been expected that these limits would be approximately straight lines, but as the work progressed it became very evident that they were distinctly curved and were surprisingly regular in form. In fact, when all the results were plotted it was found that in each case a perfectly smooth parabola could be drawn between limits, which were less than one per cent apart. These curves are shown in Fig. 2, the solid line *A* being the series without magnesia, and the broken line *B* the series with magnesia.

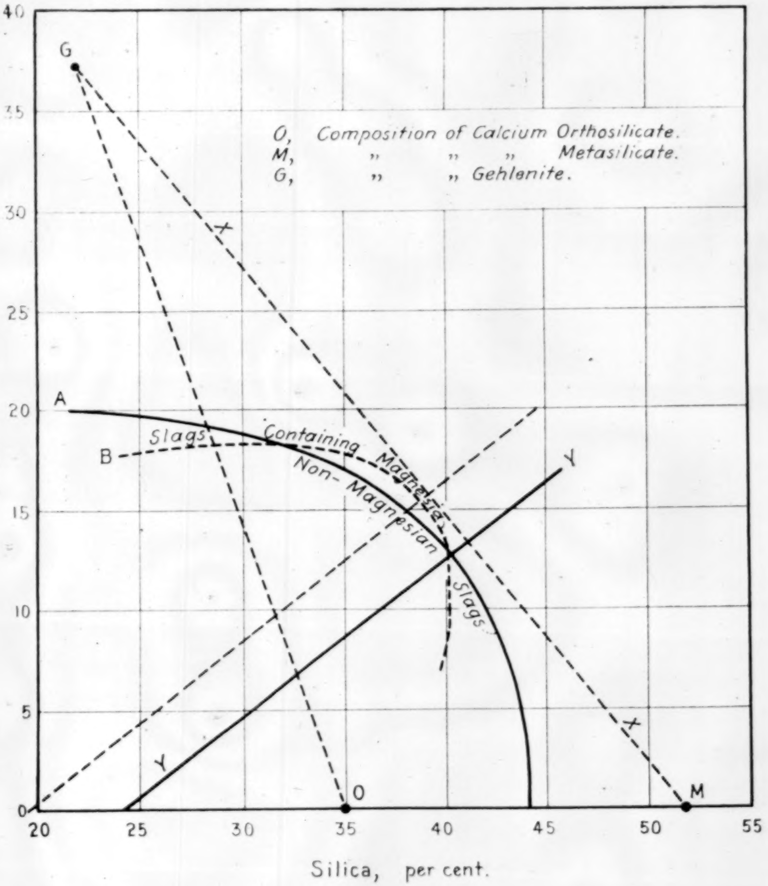

FIG. 2.

These curves were studied with some care in the hope that significant conclusions might be drawn from them. It was observed that they lie within a triangle formed by the three calculated points O, M, and G, which are respectively calcium orthosilicate, calcium metasilicate and the mineral Gehlenite, using the composition tentatively offered by Rankin and Wright, and it seemed probable that the curves were functions bearing some definite relation to these points.

If the axis YY of the first curve is taken as ordinate and the line GM as abscissa, with their intersection as origin, the equations of the two curves are

$$x^2 = 30\ (y - 1.2), \text{ and}$$
$$(x - 3.1)^2 = 11.4\ (y - 0.58), \text{ respectively.}$$

An interesting point in connection with the first curve is that it cuts the lines GO and OM at almost their middle points, indicating that at one end the critical composition would be about half Gehlenite and half orthosilicate, and at the other end half orthosilicate and half metasilicate. This fits in fairly well with the assumption that the disruptive effect is due entirely to the change of volume in the orthosilicate in passing from one crystallin form to another.

If we assumed that the three compounds given by the points G, O, and M are the ones which will inevitably form, and calculate the percentages of these compounds for various points of the curve, we find that the amount of orthosilicate is far from being a constant. Dr. E. C. E. Lord, the petrographer of this Bureau, on examining thin sections of these melts readily recognized the Gehlenite and in most cases estimated its amount at nearly the calculated figure, but he found it embedded in a matrix of glass and indefinitely crystallized matter which may or may not be orthoscilicate. Probably a slag whose composition would place it in the dangerous area would be more apt to remain sound if it contained a considerable proportion of glass.

It will be observed also that the presence of magnesia causes a considerable narrowing of the field of instability. Had time permitted the making of another series containing still more magnesia, this alteration would probably have been still more marked. It is well known that in furnaces where dolomite is used as a flux the resulting slag seldom dusts.

Without further study the writer does not feel justified in advancing any conclusions of a purely theoretical character, but proposes to consider briefly the more practical aspect. It may be objected that the foregoing data obtained from small melts made in the laboratory are not comparable with conditions in a slag bank, and that disintegration will be governed not only by chemical composition, but by a number of conditions such as mass of material, rate of cooling, presence of minor constituents, etc. Such objections are accepted in advance as entirely reasonable. The results given above may be true only for slags made under the described conditions. Yet, these results seem to be supported by the genuine slags so far studied.

The analyses of the forty slags collected from various furnaces, referred to in the beginning of this paper, were recalculated. The sulfur was assumed to be present as calcium sulfide and an appropriate deduction made from the lime content. The remaining lime, together with the silica, alumina and magnesia, were then calculated on a basis of one hundred per cent and the results plotted in Fig. 2. All of the unsound slags came inside of the curves, and all of the sound ones except three came outside. Of these three exceptions, two were unusually high in magnesia and the third was very glassy; so much so, in fact, that it could hardly be considered in the same class with most of the others. It is therefore believed that where cooling has been slow enough to insure crystallization there is a relation between chemical composition and soundness at least approximating the given curves.

An important point in connection with these experiments is that those melts which disintegrated did so very quickly. Where the composition fell well inside the curves the whole melt would crumble to dust before it was cool enough to touch. When the mixture was very close to the line on the unsafe side, dusting would sometimes not commence until the following day, but in every case it seems to have reached completion within a week. It might be expected that if calcium orthosilicate were present to any considerable extent it would set up strains which would cause the ultimate crumbling of the slag even if it did not do so immediately. But this does not seem to be the case. Some of the melts are now about ten months old, and none of the material which was sound a week after making has undergone any apparent change since. If this continues true it would indicate that there is little reason to fear for the stability of slag. If it is found free from dusting when delivered, it will probably remain so.

In conclusion, the writer would state that he is well aware that the paper is not complete either with respect to data or conclusions. A large amount of work must yet be done before we will begin to understand the matter. It is presented in its present form with the hope that it will bring out discussion from those who have worked along similar lines which may be of greater value than the paper itself.

DISCUSSION.

Mr. Bates. Mr. P. H. Bates.—If the author had plotted the composition of the slags in question in a system of triangular coordinates, in which the ordinates would represent silica, lime and alumina, he would have found that the boundary line, which he obtained in his biaxial system as defining the area in which dusting did or did not occur, paralleled to a marked degree certain isotherms as given in Fig. 8 of Rankin's original paper.[1] These isotherms in this region curve around the composition represented by $2CaO.SiO_2$. This latter exists in possibly four forms, and it is the changing from the beta to the gamma form, accompanied by a large increase in volume, that causes the dusting.

As compositions approach that of $2CaO.SiO_2$, the likelihood of dusting increases, unless the temperature of burning or the rate of cooling is increased. The compositions in question, however, followed the isotherm—hence by changing the temperature used or by cooling rapidly by quenching, it would have been possible to have approached $2CaO.SiO_2$ more nearly. In other words the boundary between dusting and non-dusting could be materially shifted or even changed in direction. The author has therefore again clearly shown the validity of Rankin's various conclusions.

The phenomena of dusting is commonly noted in cement manufacture. It can, in fact, be produced at will by low burning, or by a change in composition. Under certain conditions of product, the cement clinker may dust over a long period, but as the author states, this has not been noted in the case of blast-furnace slags. However, certain slags, reported as basic open-hearth, have been noted to dust continuously over long periods.

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[1] Rankin, "The Ternary System $CaO—Al_2O_3—SiO_2$," *Amer. Jour. Science*, XXXIX, January, 1915.

A COMPARISON OF THE RESULTS OF THE SLUMP TEST AND THE FLOW TABLE IN THE MEASUREMENT OF THE CONSISTENCY OF CONCRETE.

By W. L. Schwalbe.

In a test at Purdue University during August, 1920, on a Koehring Concrete Mixer to determine the effect of the time of mixing on the consistency and strength of concrete, the consistency was measured mainly by the use of a Bureau of Standards Flow Table. Enough measurements were made by means of the slump test so that a comparison of the two methods is possible.

A complete statement of the method and results of the test on the mixer is given in a paper on "Tests of a Concrete Mixer," by Prof. W. K. Hatt, presented at the annual convention of the American Concrete Institute in 1921. Acknowledgments are made to Professor Hatt of Purdue University and to Mr. K. H. Talbot of the Koehring Machine Co. for their permission to use the data obtained during the test. All of the consistency tests were made by the writer with an assistant.

Measurements of Relative Consistency.

The flow table[1] used consisted of a tin-covered circular wood table 30 in. in diameter mounted on a $\frac{3}{4}$-in. shaft. By means of a cam on a horizontal crank shaft the table and shaft could be raised $\frac{1}{2}$ in. and allowed to drop freely the same distance once per revolution of the crank. The concrete was placed in a truncated conical form with a top diameter of 7.5 in., a bottom diameter of 11.3 in., and a height of 5.5 in., on the center of the table. Each 4-in. layer of concrete was lightly rammed with a $1\frac{1}{2}$ by $1\frac{1}{2}$-in. square rod. After removal of the form the table was raised and dropped fifteen times at a uniform speed and the increased diameter was measured. The percentage of the original diameter was taken as the relative flowability.

The procedure for the slump test applied to the concrete was similar to that described by the Society's Committee C-9 on Concrete and Concrete Aggregates.[2] The concrete was placed in a truncated conical mold with a top diameter of 4 in., a bottom diameter of 8 in., and a height of 12 in., and tamped as in the flow table test. The decrease in height or slump upon the removal of the form vertically upward was taken as the measurement of the relative consistency.

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[1] G. M. Williams, *Engineering News-Record*, May 27, 1920, p. 1044. .

[2] *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part I, p. 304 (1920).

The concrete was made with Lehigh Portland Cement and washed sand and gravel from Lafayette, Indiana. A batch consisted of 2½ bags of cement, 5 cu.ft. of sand and 7½ cu.ft. of gravel measured by volume. The sand and gravel were weighed before being dumped into the skip. The gravel was usually placed in the hopper first, then a bag of cement with the sand following, and lastly the remainder of the cement. A predetermined amount of water from the mixer tank was discharged into the drum during the time that the skip was emptying its load into the drum. During the discharge of the concrete after a set mixing time, a sample of the batch was taken near the beginning, one near the middle and a third near the end of the discharge. The samples, which were from ½ to ¾ cu.ft. in volume, were immediately tested on the flow table in the order in which they were taken. The third sample was also tested by the slump method after it had been on the flow table. The duration of time from the catching of the first sample to the completion of the slump test was from seven to eight minutes.

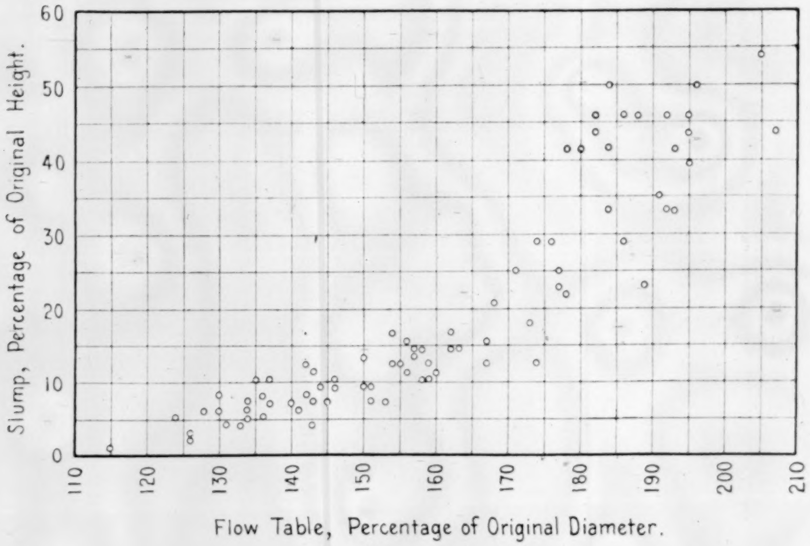

FIG. 1.—Results of Slump and Flow Table Tests.

RESULTS.

For the comparison of flow table and slump test results, the third observation only of the flow table test is used since the only slump test was made on the third sample. The results of the flow table and slump tests are shown in Fig. 1. Of the 88 slump tests made, 66 per cent show a decrease in original height or slump from 0 to 20 per cent, and 34 per cent, from 20 to 60 per cent slump. Of the 88 corresponding flow table tests, 1 per cent shows an increase in diameter from 0 to 20 per cent, 55 per cent from 20 to 60 per cent increase in diameter, and 44 per cent from 60 to 110 per cent. The wider range of the flow table test is thus clearly brought out.

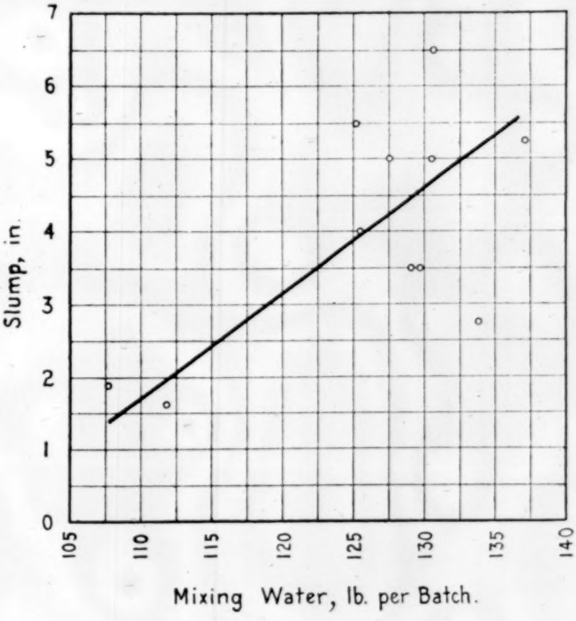

FIG. 2.—Relation Between Mixing Water and Slump Tests.

For a direct comparison of the slump and flow table results, the variation of consistency with the amount of mixing water in the batch is shown for the slump test in Fig. 2, and for the flow table in Fig. 3. The results for a mixing time of one minute only are plotted, since the concrete reached its full flowability in that time. It will be noted that the points showing the variation of consistency with mixing water by the flow table are less scattered than the points showing the same variation as measured by the slump test. The flow table consequently shows a more definite increase in the flowability of the concrete with increased amount of mixing water than the slump test.

As has already been stated, three flow table observations were made with each batch of concrete, one near the beginning of the discharge from the mixer, one at the middle, and one near the end of the discharge. The three values were averaged, and the deviation of each single observation from this mean was calculated. Out of 264 observations, 17 observations diverge more than 7 per cent from the average of the three, and 4 more than 10 per cent. The average divergence from the mean of the three was 2.8 per cent. The mean observations were grouped in order of flow table value, and the average deviation of the first, second and third observation of each group calculated. The results are shown in Fig. 4. It may be noted that the third observation is generally below the other two. Considering that the data include results for five different times of mixing and a wide range of consistency, it may be said that this comparison, made under widely different conditions, shows relatively little variation in the flow table measurements.

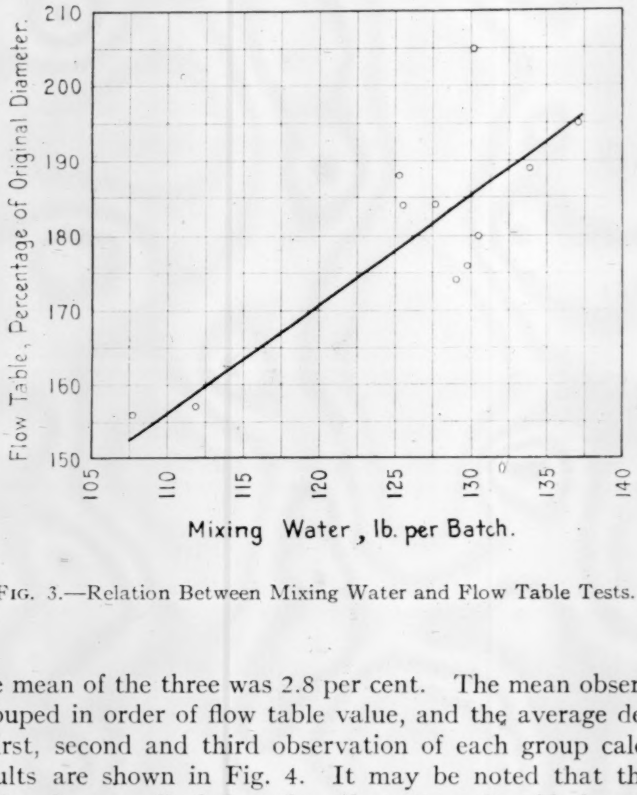

FIG. 3.—Relation Between Mixing Water and Flow Table Tests.

SUMMARY AND CONCLUSION.

Consistency measurements were made in this test for the purpose of showing how the consistency varied with the time of mixing in a given mixer. The comparison of results as obtained by the slump and flow table tests is made for the purpose of showing which method proved the more reliable. In addition to a direct comparison of the two methods, the flow table test is investigated statistically to determine whether this test is intrinsically a reliable one in so far as repetition of result for the same consistency is concerned.

The conclusions arrived at from a study of the observations made by the two methods may be summarized as follows:

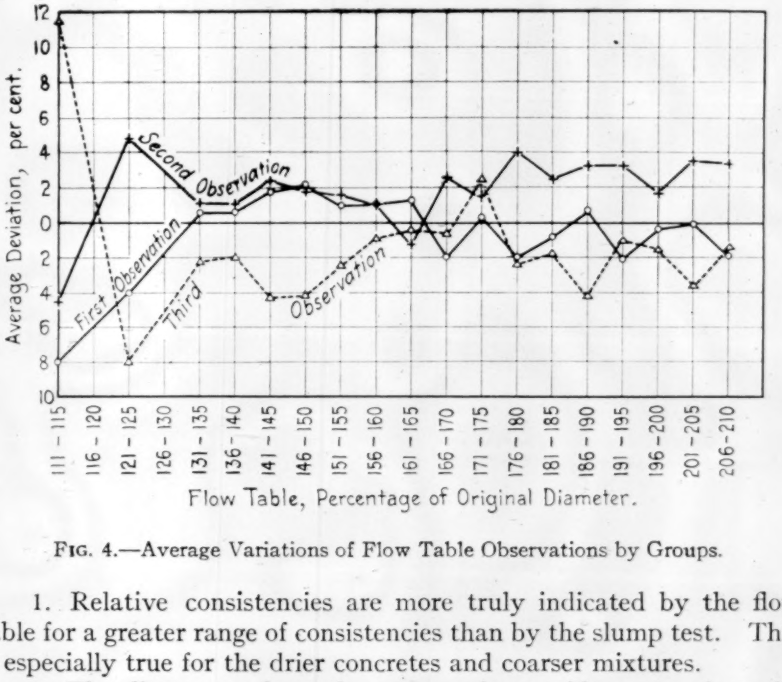

FIG. 4.—Average Variations of Flow Table Observations by Groups.

1. Relative consistencies are more truly indicated by the flow table for a greater range of consistencies than by the slump test. This is especially true for the drier concretes and coarser mixtures.

2. The divergence from the average for a wide range of consistencies under different conditions is relatively small for the flow table, notwithstanding that the third sample, by reason of the non-uniformity of the batch, was usually coarser than the other two samples and consequently showed a less flow.

3. In general, for a large scale production of concrete under approximate field and laboratory conditions, the flow table was found to be the more satisfactory method of measuring the consistency.

DISCUSSION.

Mr. Davis. MR. WATSON DAVIS (*presented in written form*).—To those of us who have been interested in the development of the flow table because we felt that the slump test could be improved upon, Mr. Schwalbe's conclusions are gratifying.

I should like to present very briefly a few conclusions of tests that we have been making at the Bureau of Standards, comparing our form of flow-table test with the truncated-cone slump test.

1. The slump test measures consistency with more accordance to the flow-table test when the mixes are rich in cement or are easily working because of high sand content. Specifically, to take extremes, while slumps of 0 to 9 in. correspond to flows of about 120 to 250 on our table when a 1:1:2 mix is used, the flow-table range for similar slumps when a 1:3:6 mix is used is only from 190 to 250. In other words, the slump test does not begin to get to work in the case of a harsh lean mix until the mix is quite wet, or the range of its use is smaller. A 1:1:2 mix of 1 in. slump would have a flow of about 130, while a 1:3:6 mix of the same slump would have a flow of nearly 200. This is a real difference in consistency.

2. The variation in making repeated tests on the same batch of concrete with the flow table is less than when performing the same process with the slump apparatus, and this is more true with the leaner and harsher mixtures.

In this connection it may be pointed out that the slump test was first successfully applied to control of concrete consistency when rich, easily working mixes were being used in concrete ship construction, and that it does this job very well.

Mr. Chapman. MR. CLOYD M. CHAPMAN.—The discussion of this paper and of that of Mr. Davis has been very interesting, to me especially. The flow table probably was first built in 1912, and experiments carried on at that time led those who worked with it to believe that it had possibilities. In order to promote the development of those possibilities and to insure standardization of the instrument, a patent was taken out on the process and apparatus and that patent was offered to the Society for their supervision, so that the control of the manufacture of the instrument might be under the direction of the Society. The Executive Committee of the Society concluded that that was not part of its business and declined the offer. It is necessary, or desirable at any rate, that this instrument be standardized.

Mr. Chapman. As the Executive Committee has somewhat altered their policy during the past year and have permitted a patented instrument to be specified in a standard method of making tests advocated by this Society, they might now consider assuming the supervision of this instrument. It may then be developed under the direction of the proper committees and be brought to a state of perfection that will enlarge its field and make it suitable not only for consistency but possibly for time of set and possibly for use with other materials than concrete. It may be useful for measuring the plasticity of lime mixtures and possibly clay mixtures. If the Executive Committee saw fit now to take up the responsibility of administering this patent for the benefit of the public, I have no doubt that the offer will be readily renewed.

Mr. Hatt. MR. W. K. HATT.—The following factors enter into the condition called consistency:

Amount of water;
Amount of cement;
Mechanical grading of aggregate;
Character of cement;
Absorption of aggregate;
Time of mixing;

The term "consistency" is not well chosen. Perhaps "flowability" would be better. Generally diagrams are drawn showing the consistency to increase with increasing water and have "relative consistency" of 1.0, 1.25, etc., with increasing water; but with an excess of water the mixture does not hold together. It does not "consist." At the other end of the scale, a dry mixture does not consist.

In measuring "consistency," therefore, we should keep our eyes open to the condition of the concrete, and note if the mix is a practical and usable product.

The consistency values are often expressed as fractions of the total dry weight of the materials, or again, as fractions of the water-cement ratio. Neither one is uniquely determinative.

At Purdue University a large number of comparisons have been made of the flowability as measured by the Roman cone test and the flow table. The latter is usually ascribed to the Bureau of Standards, but Mr. Chapman speaks of his earlier use of the apparatus. Figs. 1 and 2 are included, showing the relation between flowability and percentage of water and water-cement ratio.

In choosing a measuring instrument for the test of the Koehring Mixer, we had recourse to both the Roman cone and the flow table.

Mr. Hatt. It appears to us that the latter is a more delicate and reliable test instrument than the former.

A delicate test is indeed needed, because it soon became evident that as small an amount of water as 4 lb. in a batch of 1500 lb. dry weight of materials would change the flowability of the concrete sufficiently to appear in the measuring instrument as a change of 10 points in the flow table, from 160 to 170.

Many other comparisons have been made in an investigation of the concrete-making properties of Indiana sands and gravels.

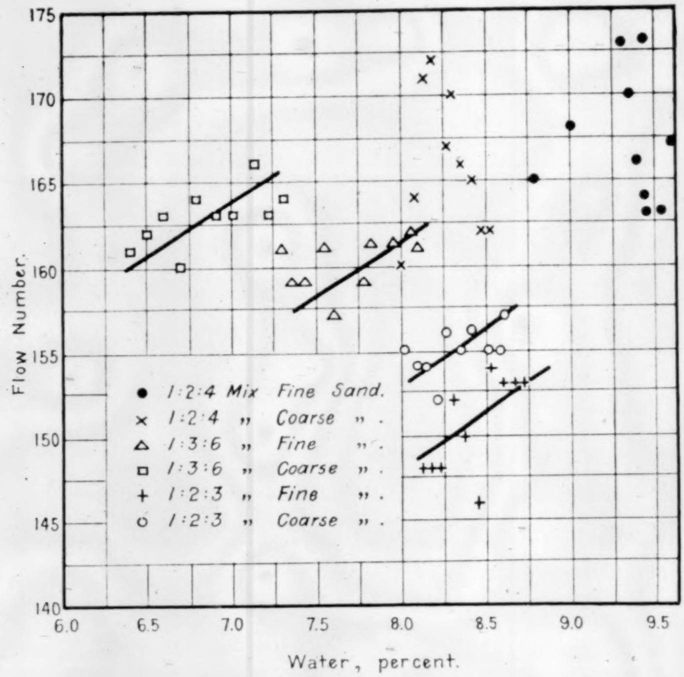

FIG. 1.—Relation Between Flow Number and Percentage of Water. Water expressed as Percentage of Combined Weights of Gravel, Sand and Cement.

Mr. Talbot. MR. ARTHUR N. TALBOT.—This matter of the determination of the workability of concrete is, to my mind, one of the most important questions in concrete. These two instruments, the slump-test apparatus and the flow table, are certainly advantageous in the determination of the workability of the material. I feel, however, that neither one is near enough perfection to be taken as the final method to be used. I have given a good deal of attention to the matter for several years, and I have been hopeful that someone would devise an apparatus

Mr. Talbot. which would be superior to these instruments. Mr. Schwalbe, the author of this paper, spent several months of his time a year ago in devising and working out different instruments. He made a centrifugal machine in which, as the material was rotated, the surface of revolution formed could be measured. It gave good results, but the time element, the viscosity, varied so largely that it was not considered a practicable method. He had another thing in the form of a stirring machine or mixer where the material was rotated and a device pushed the material to one side as it passed around, the amount of electric current necessary to overcome the resistance to motion being measured. In another device the concrete was pressed through a nozzle and the pressure found necessary was measured. I had investigated a method using a rubber tube of the diameter of a large automobile tube, which was filled with the concrete. A plunger under a known weight forced the material down and expanded the tube, causing the particles of the concrete to move over one another. Knowing the resistance of the rubber, which could be easily determined by using

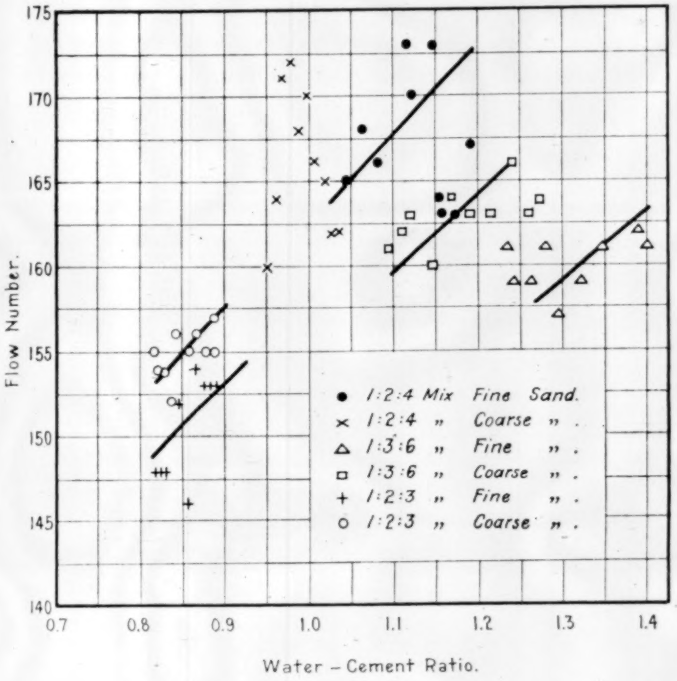

FIG. 2.—Relation Between Flow Number and Water-Cement Ratio for Gravel Concrete.

Mr. Talbot. water instead of concrete, the mobility of that material (or the friction of the particles) as compared with perfect material, could be determined. Unfortunately I had overlooked the fact, which I afterwards found out in tests on the ballast of railroad track, that the pressure on that column was not the same throughout a cross-section, and that most of the load was taken at the middle of a section, while the outside was expanding without much load coming on it. Mr. Schwalbe expects to keep at this, and I hope that others will work on the problem, for there is urgent need of finding a method which will determine the mobility or the workability of concrete and will be applicable for different richnesses, for different values of the proportions of the various aggregates, for variations in the water, and for other variations that come in the materials.

Mr. Williams. Mr. G. M. Williams (*by letter*).—The test data and conclusions presented by Mr. Schwalbe relating to comparative tests of the "slump" and "flow table" methods of measuring consistency of concrete bear out the conclusions drawn from other tests and observations in which the two methods have been compared.

However, it would appear that the data as presented is of more value in (1) showing the variation in consistency of different batches of concrete prepared with equal quantities of mixing water and (2) the segregation of concrete during mixer discharge, rather than the inherent merits or demerits of either type of apparatus.

Referring to Fig. 3 it is stated that "the points showing the variation of consistency with mixing water by the flow table are less scattered than the points showing the same variation as measured by the slump test. The flow table consequently shows a more definite increase in the flowability of the concrete with increased amount of mixing water than the slump test." The statement in the first sentence is borne out by the test data, but the second implies that the wide differences in flowability found for the same quantity of mixing are due to errors of the method. No doubt most readers who have not had experience with the flow table will not be favorably impressed by a method of consistency measurement which will show values varying from 176 to 205 for similar batches of concrete in which the same weights of water are used. Rather than indicating defects in the flow table method these values indicate wide differences which will be found in different batches of concrete in which wet aggregates are used, when the greatest care is taken in attempting to determine the actual quantity of water in the batch. Even with air dry aggregates the use of equal quantities of water will result in concretes of appreciable different consistencies due to unavoidable differences in sand gradation.

Mr. Williams.

The true error of the flow table method, which will include errors due to the particular method of manipulation employed by the operator can be determined only by consecutive flow measurements of the same batch of concrete, all being made a suitable time after mixing water has been added to allow for absorption which may cause a marked stiffening during the first 5 to 15 minutes.

The data shown graphically in Fig. 4 indicates the tendency to segregate during discharge in the particular mixer employed in the tests, rather than errors in the flow table method itself. Even after the most thorough mixing and the concrete in the mixer appears to be homogeneous there is a tendency to segregate during the period of discharge which is dependent upon type of mixer, richness of mix, relation of size of batch to mixer capacity, and consistency of the mix. In general, the first portion of the discharge is wettest owing to the fact that it contains a larger percentage of the fine material while the last portion usually contains an excess of coarse aggregate. Consistency or flowability is dependent not only upon the wetness but upon the relative amount of the cement and fine aggregate in the sample chosen for test. The flowing property is almost entirely due to the condition of the fine material of the batch and its amount. The presence of the excess of coarse material at the end of the discharge is well shown by the values shown for "Third Observation." While these values show a high efficiency for this particular mixer they do not in themselves furnish a basis for conclusions as to the accuracy of the flow table apparatus.

The variation in flow table measurements with increase in water content are shown in the May 27, 1920, issue of the *Engineering News-Record*. The following results indicate variation in consecutive flow table readings on separate batches of concrete, prepared at different times. To eliminate changes in flow due to absorption, tests were made 15 minutes after the mixing water was added. A flowability of approximately 200 was used, since this is one commonly employed in practice. Results in each group should be compared separately.

CONCRETE BATCH NO. 1.		CONCRETE BATCH NO. 2.		CONCRETE BATCH NO. 3.	
TEST NO.	FLOWABILITY.	TEST NO.	FLOWABILITY.	TEST NO.	FLOWABILITY.
1	203	1	202	1	199
2	203	2	199	2	200
3	203	3	199	3	195
4	202	4	201	4	197
5	201	5	201	5	195

The above results indicate variations in flow determinations which may be charged to errors in the method and the operation of

Mr. Williams. the apparatus. It is seen that such errors and variations which may be fairly charged against the apparatus are negligible when other variable factors which enter into the preparation of concrete are considered. The results can only be as accurate as the sample which is selected for test. Care must be employed to obtain a representative sample in each case in order to obtain such consistent values as the foregoing.

Mr. Schwalbe. MR. W. L. SCHWALBE (*Author's closure by letter*).—Our tests indicated that the slump test shows a decided lack of agreement for similar samples of concrete. This lack of agreement of course obscures variation in relative flowabilities. However, fine agreement of result on carefully prepared samples of the same mixture does not indicate absolute lack of error in method in the comparison of relative flowabilities of varying mixtures. It is felt that the flow table is far more accurate than the slump test in this respect, yet other methods will no doubt show greater accuracy than the flow table. Further experimental work is needed.

TIME OF SET OF CONCRETE.

By Watson Davis.

The "time of set" of concrete is an important property to which little attention has been given. Specifications for the time of set of neat cement, the principal active ingredient of concrete, have been formulated and used. Much investigational work has been done using the Vicat and Gillmore-needle methods of measuring time of set of neat cement, and the literature is filled with reports of setting time tests of neat cements of "normal consistency."

But a measure for the setting qualities of concrete and mortar, the forms in which cement is used commercially, has not been developed heretofore. This paper presents a method, which may be called the "flow" method, for measuring time of set or rate of stiffening of concrete. Data and examples of its use in determining some of the principal factors influencing the setting of concrete are presented.

Method.

Briefly, the method consists of determining the time at which the concrete ceases to "flow," or when it is no longer plastic. This is accomplished by using the "flow table," an apparatus developed at the Bureau of Standards for measuring the consistency or "flowability" of concrete.[1]

The "flow table" is a table-like apparatus consisting of a rigid frame with a top mounted on a vertical shaft so that it can be jolted or allowed to drop through a fixed height by means of a rotated cam. A mass of concrete, usually in the shape of a disk or truncated cone, is placed on this table top, jolted a given number of times, and its increased diameter measured by means of calipers. The diameter after jolting divided by the original diameter and multiplied by 100 gives a figure which is a criterion of "flowability" or consistency.

The flow test for consistency of concrete and the flow test for time of set of concrete are intimately connected. In the test for time of set, the rate of decrease in flow is measured as follows: A number of

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[1] G. M. Williams, "Flowability of Concrete," *Engineering News-Record*, May 27, 1920.

While the flow table apparatus as used in obtaining the data of this paper and as now used in other laboratories for testing the consistency of concrete was independently developed at the Bureau of Standards during the early part of 1919, it should be noted that Cloyd M. Chapman in U. S. Patent, 1,233,843, filed February 21, 1913, granted July 17, 1917, describes fully the principle that underlies the flow table. Claim 3 of his patent reads:

"The method of testing the consistency of plastic material which consists in molding the material to a definite size and shape, releasing the molded mass from restraint by the mold, and then subjecting the molded mass to a definite jarring, and measuring the increase which takes place in a lower horizontal dimension thereof."

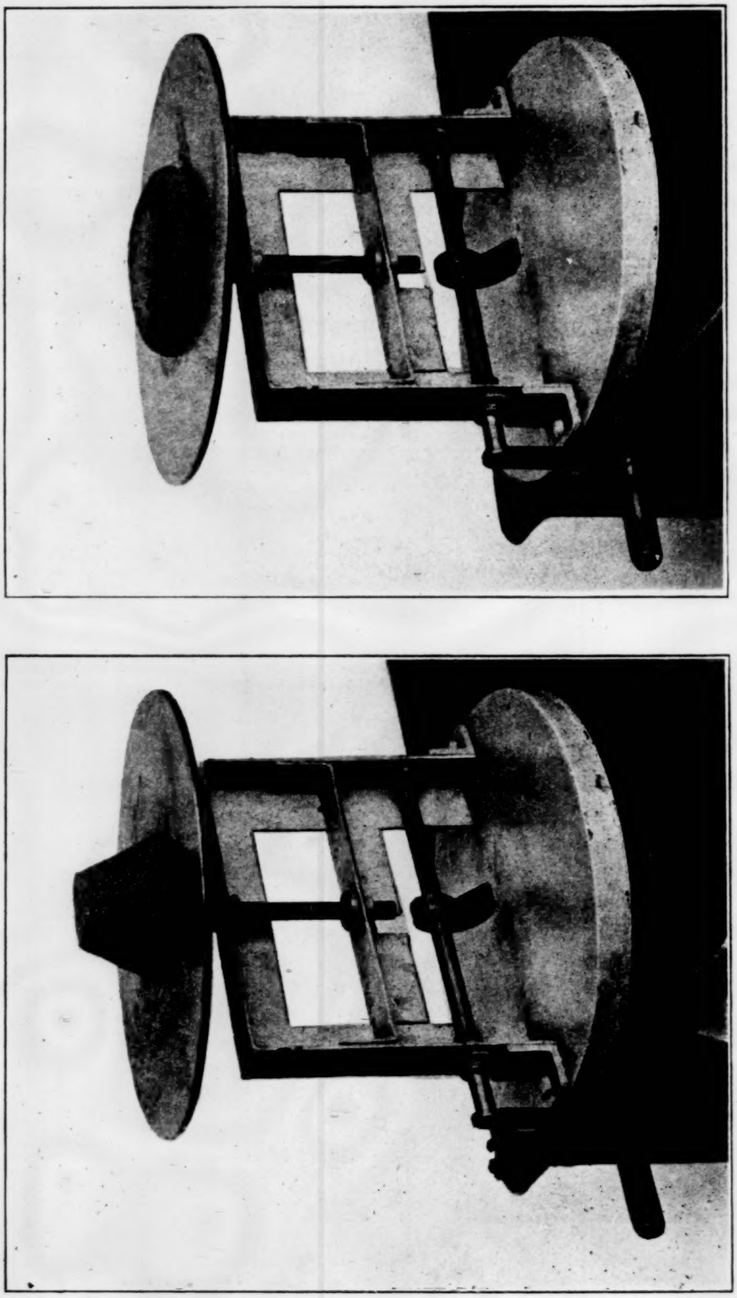

FIG. 1.—Small Flow Table Before and After a Test for Flowability.

disks of concrete are molded and at stated time intervals after mixing are tested in succession for flowability. At the beginning of the test the disks are jolted at intervals of an hour, but the intervals between joltings are decreased as the flow decreases. As the concrete stiffens the flow decreases, and the time at which the point of no flow is reached is considered the time of the set of the concrete. In practice, a flow of 105 is usually considered the point of no flow.

APPARATUS.

Necessary apparatus for making the tests consists of a flow table, and sufficient molds and calipers for measuring the spread of concrete on the flow table. Two sizes of flow tables were used. The large table[1] (designated D) has a 36-in. top while the small table (designated C) has an 18-in. top. The latter is illustrated in Fig. 1. A cylindrical mold, 6 in. in diameter and 3 in. high, made of light sheet metal bent into cylindrical shape and fastened with a small clamp, was used for tests on Table D. For use in some tests on Table C, a smaller mold in the shape of a truncated cone—the shape usually used for flow tests for consistency—was used. This mold, also made of sheet metal similarly fastened, measured 4 in. in bottom diameter, 2 in. in top diameter and 2 in. in height. A small disk mold 2 in. diameter, 1 in. high, was used for molding test specimens for the neat cement tests. Except when indicated, Table D had a $\frac{1}{2}$-in. drop and was jolted 15 times, and Table C had a $\frac{1}{2}$-in. drop and was jolted 50 times. Although the actual figures for flow are influenced by the flow table and molds used, the setting times determined are not materially affected. The time of set is taken as the time at which the concrete will not flow when jolted, and set concrete cannot be made to flow by more vigorous jolting.

DISCUSSION OF TESTS.

Effect of Consistency on Set.—That the wetter the consistency the slower will be the set seems to be a general law, so long as cement, mix, and aggregates are the same. In every case in the data obtained an increase in initial flowability of a given mix is accompanied by an increase in the time of set. Except for the influence of the setting quality of the cement itself, excess water producing wetter concrete is the most important factor influencing the time of setting of concrete. The retardation of set is most marked in the leaner mixes.

Fig. 2 shows the influence of wetness or consistency on the rate of setting of 1 : 1$\frac{1}{2}$: 3 concrete. This diagram presents average curves of tests made on three consecutive days. Data on 24-hour strengths are also included.

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[1] Illustrated in *Proceedings*, Am. Soc. Test Mats., Vol. XX, Part II, p. 243 (1920).

The effect of different percentages of water on the setting of a neat cement are shown in Fig. 3, which gives average curves of tests, repeated three times, of the time of set of neat cement when gaged with 22, 23, and 24 per cent of water. Data on 24-hour strengths are also presented. These results indicate that for each per cent increase in the gaging water the time of set is lengthened on the average about 20 minutes. Time-of-set tests on neat cement using 25 and 30 per cent of water also confirm this conclusion.

Effect of Richness on Set.—A rich concrete will set faster than a lean concrete, provided the two concretes are of the same consistency or initial flowability and are made of the same materials. In Fig. 4 are plotted time-of-set tests on neat cement, 1 : $1\frac{1}{2}$: 3 concrete, and 1 : 3 : 6 concrete of approximately the same relatively wet consistency. These curves are the average of four tests of each mix on different days, and show the variation in set with richness for the consistency given. Other tests not reported show that the effect of richness on set is minimized when the consistency is so dry that only a small decrease in flowability is necessary to cause the concrete to reach the point of no flow or to become set.

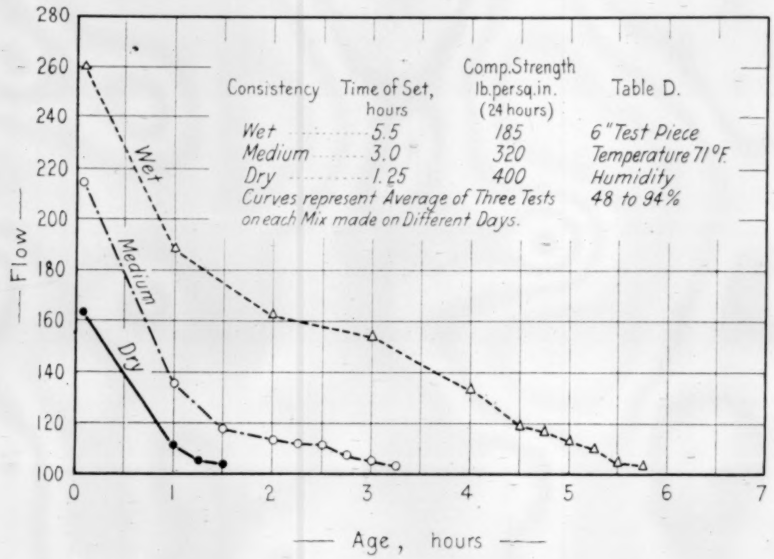
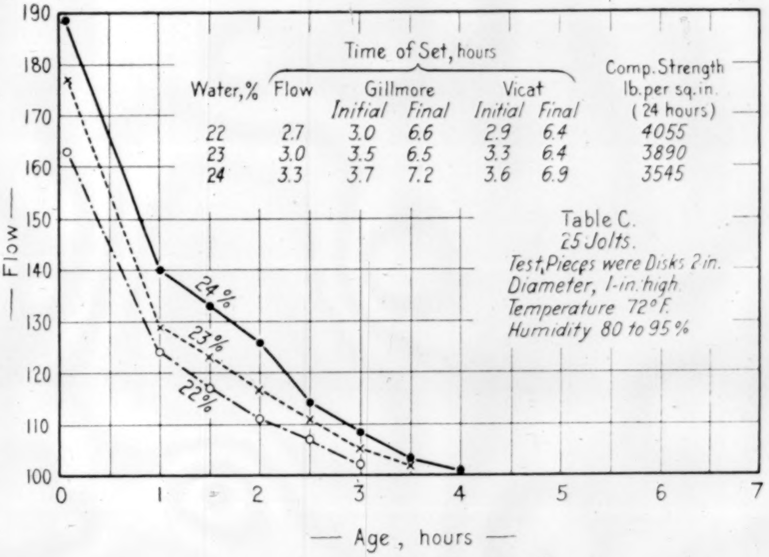


FIG. 2.—Effect of Consistency on Set of 1 : $1\frac{1}{2}$: 3 Mix.

Effect of Character of Cement on Set.—The character of the cement is undoubtedly the most important factor that influences the setting time of concrete. Variation of gypsum content, method of manufacture, raw materials and fineness all affect the setting properties of the cement and these properties of the cement are reflected in the concrete in which the cement is used. In view of the fact that it is generally recognized that cements of different character may have widely different setting times, the tests reported in Figs. 5 and 6 were not carried to the point where they would be rigorously conclusive, and represent results of single tests only.

Cement U is a natural cement that is fairly quick-setting. Cement L is a Portland cement that has normal setting properties, while Cement S is a Portland cement that is abnormally slow-setting. Setting tests of these three cements in a neat mix are shown in Fig. 5. The percentages of water determined by the routine specification test for "normal consistency" made by the Vicat needle were used and this accounts for the discrepancy in the initial flow shown by cement L.



Water, %	Time of Set, hours					Comp. Strength lb. per sq. in. (24 hours)
	Flow	Gillmore		Vicat		
		Initial	Final	Initial	Final	
22	2.7	3.0	6.6	2.9	6.4	4055
23	3.0	3.5	6.5	3.3	6.4	3890
24	3.3	3.7	7.2	3.6	6.9	3545

Table C.
25 Jolts.
Test Pieces were Disks 2 in. Diameter, 1-in. high.
Temperature 72° F.
Humidity 80 to 95 %

FIG. 3.—Effect of Various Percentages of Water on Set of Neat Cement.

Fig. 6 shows the result of using these cements in 1 : $2\frac{1}{2}$: $3\frac{1}{2}$ concrete.

While the setting properties of the cement determine in a large measure the setting properties of the concrete, in general, the differences between the setting times of concretes have a tendency to be less than those between the setting times of corresponding neat cements.

For the tests reported in all figures except Figs. 5 and 6, normal setting cements were used. Although different cements were used in the tests of Figs. 7 and 8, the range of setting times determined by the Gillmore needles on neat cements of routine "normal consistency" was only from 4.5 hours to 5.9 hours for initial set and from 7.5 hours to

8.4 hours for final set. Cement used in tests Figs. 2 and 4 had setting times of 3.7 hours and 7.1 hours for initial and final sets, respectively, by the Gillmore needles.

Relation of Time of Set of Neat Cement and Concrete.—As pointed out above, neat cement sets faster than the concrete made from it. Conditions of temperature, aggregate, cement content and consistency materially affect the setting time of concrete, and while the setting properties of the cement as determined by a needle test on a neat mix of normal consistency are reflected in the concrete, they are changed and influenced by the conditions peculiar to the concrete. For these reasons it is believed that to determine the setting properties of concrete, tests must be made on the concretes themselves.

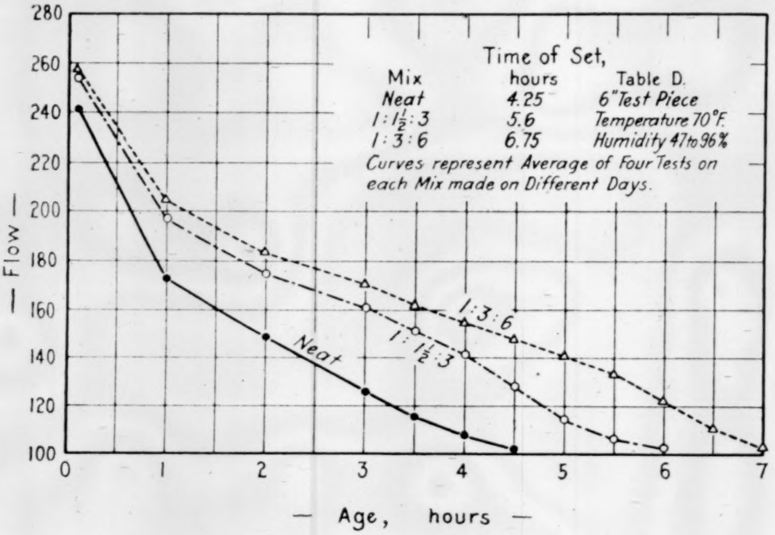


FIG. 4.—Effect of Cement Content or Richness on Set.

Effect of Calcium Chloride on Set.—The data in Fig. 7 show the effect of gaging, 1 : 2 : 4 concrete with solutions of calcium chloride. Two calcium-chloride solutions were used. One referred to as "Compound X" is sold under a trade name and is approximately a 30-per-cent solution of calcium chloride. The second solution was made from commercial calcium chloride. Both solutions, before using in the mixes, were diluted to contain 4 per cent of calcium chloride. The same cement, aggregates, proportions and consistency were used in all mixes compared, and the calcium chloride was the only variable introduced. In all cases the 4-per-cent calcium-chloride solution caused the set to take place in about half the time required by corresponding mixes gaged with plain water. The two calcium-chloride solutions from different sources, but of the same concentration, had practically the same effect on set.

Effect of Temperature on Set.—The variations in time of set caused by differences in temperature are shown graphically in Fig. 8. All test specimens were molded from one batch of 1 : 2½ : 3½ concrete under normal temperature conditions and then subjected to the temperatures and conditions stated in the figure. Both the high and low temperatures are met with in practice. The "low" temperature was just above freezing, while "high" temperature corresponds to that sometimes experienced in midsummer. Concrete at "low" temperature took over 2.5 times as long to set as that at high temperature, and the concrete of normal temperature set 4 hours before the cold concrete, and 1½ hours after the "high" temperature concrete.

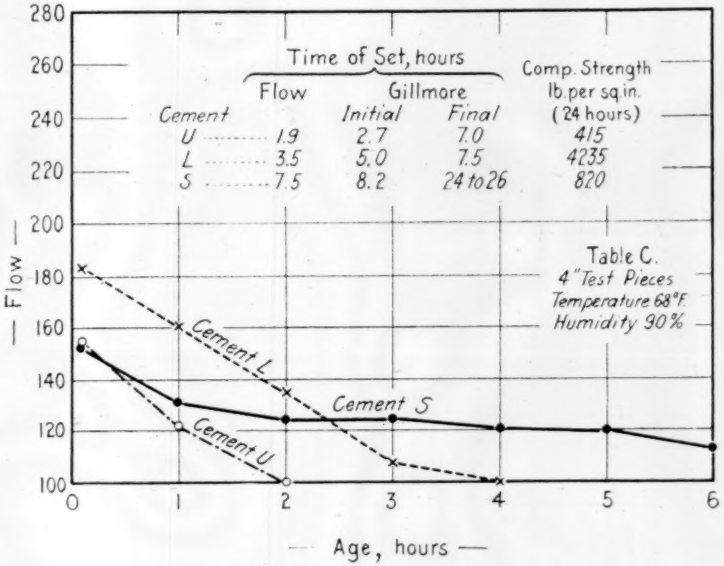


FIG. 5.—Effect on Set of Character of Cement in a Neat Mix.

Strength tests on 3 by 6-in. cylinders kept 24 hours under the different temperature conditions were made and the average of three tests at 24 hours under each condition showed that at high temperature the strength was 2.5 times normal temperature strength and at low temperature the strength was one-sixth that at normal temperature.

While it is possible that concretes made of cements of different composition and manufacture would not always exhibit these large differences in set and strength due to temperature, undoubtedly the results presented are indications of what may be expected. In general the lower the temperature the slower a given concrete will set, and the higher the temperature, the faster it will set.

Method of Measuring Set of Neat Cement.—In the tests of Figs. 3 and 5, time of set of neat cement by both the needle and flow-table methods were obtained. The results indicate that the flow method gives times of set that are somewhat earlier than those for initial set given by the Gillmore needle. Tests reported in Fig. 3 indicate that time of initial set by the Vicat needle is about the same or slightly earlier than the initial set by the Gillmore needle.

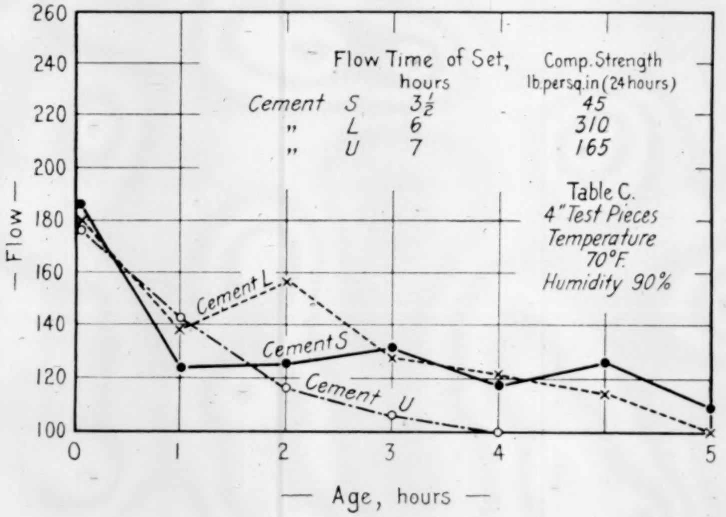


FIG. 6.—Effect on Set of Character of Cement in 1 : 2½ : 3½ Mix. (Aggregate was Limited to a Maximum Size of ½ In.)

The flow method of measuring time of set is fundamentally different from the Gillmore and Vicat methods. In the Gillmore test only a portion of the outer surface of the pat is tested. The Vicat test depends upon the penetration of a needle into a relatively small portion of the pat. When the flow time-of-set piece is jolted on the flow table, the entire mass is affected.

The flow method could be used for routine setting tests of cement. Two set test pieces could be made of normal consistency paste and one tested at 1 hour and the other at 7 hours. Provision could be made that a flow of 105 should not be reached when 1 hour old but that it should be reached by the end of 7 hours.

Incidentally it is believed that the flow table is a better apparatus for use in determining "normal consistency" of neat cement than the Vicat apparatus.

Nature of the Flow Changes Occurring during Setting.—The rate of the change in flowability that takes place during the setting seems to be influenced by the consistency and cement content of the mix. When the mix is of small initial flowability or is rich in cement content, a large part of the flow (50 to 75 per cent) is lost in the first hour after mixing. When the mix is of wet consistency and has a small cement content, the decrease in the first hour after mixing is smaller on a percentage basis, but during this first hour the rate of decrease is usually higher than during any other period. A probable explanation of these initial decreases is that they are caused by a combination of setting and absorption. The cement and aggregate gradually absorb water during this period, thereby doing their share in decreasing the flowability.

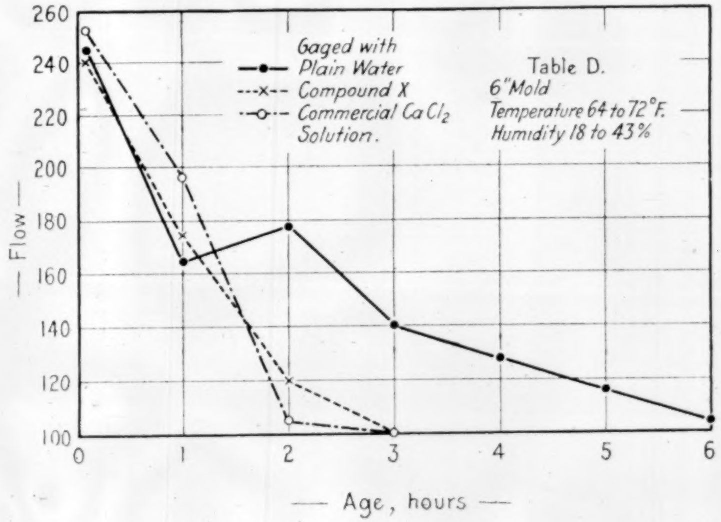


FIG. 7.—Acceleration of Set Caused by Gaging 1 : 2 : 4 Concrete with Calcium Chloride Solution.

Tests not reported show comparatively rapid decrease in flowability determined at short intervals (3, 5 and 10 minutes) after mixing, showing that there is a stiffening of the mix due to absorption in the first few minutes during and after mixing. While this absorption of water is comparatively more rapid in the first 10 minutes during and shortly after the mixing, the absorption is probably not completed then. Although diminished, it probably continues through the first hour or more after mixing, and combined with a true setting action, causes the initial decrease referred to above.

It was thought that the relatively large decrease in flowability noted above might be due to an actual loss in water by evaporation or other cause. Weighings of several test specimens of the various series were therefore made to determine this possible loss. While specimens stored in air at low humidity showed losses of water, those stored in the moist cabinet at high humidity did not. As initial losses in flowability are noted in both cases it is concluded that loss of water is but a minor contributory cause. It was noted that a considerable loss was due to leakage of water from the test specimen in the case of the wetter mixes, and not to evaporation.

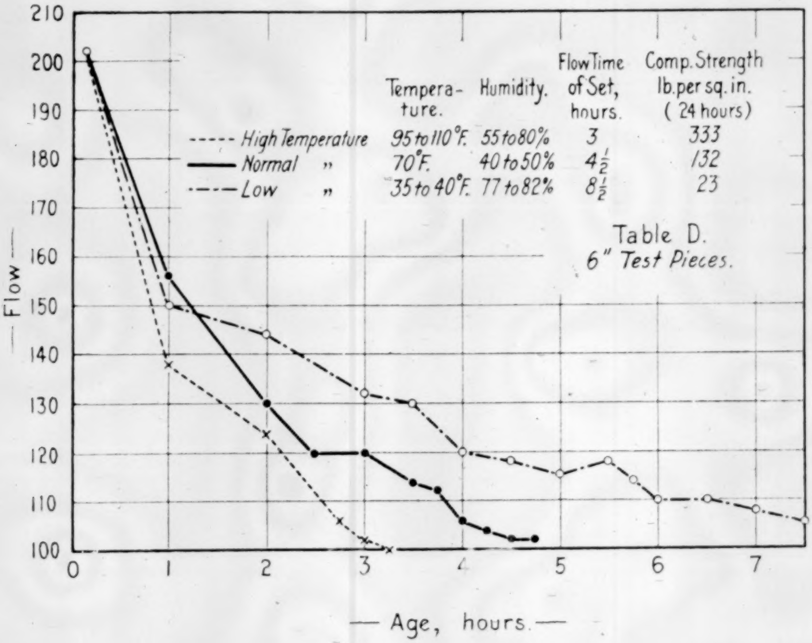


FIG. 8.—Effect of Temperature on Set of 1 : 2½ : 3½ Concrete.

Early Strength as a Measure of "Final Set."—That flow time of set corresponds approximately to the initial times of set by the needle methods when used for neat cement has been shown in data presented above. But the final set tests by the needle methods can be applied only to neat cements, and even then are of no real use and require much time to complete. The test needed is one that will tell the condition of the concrete at an early age and give definite information that can be used in deciding when to pull forms, or to perform some other operation. A compressive strength test at an early age, say 24 hours, will give such information. A test of this kind is suggested as a substitute for tests of final set.

Twenty-four hour compressive strengths are reported in Figs. 2, 3, 5, 6 and 8. Early strengths necessary for different purposes could be determined and specified. Some cases where such a test would be important are to determine time for removal of forms, ability to carry the dead load of structure, and the opening of concrete-paved sidewalks and streets to traffic.

There is no general relation between time of set and strength. Reference to Figs. 5 and 6 will show that the fastest setting mixes are the weakest while the slowest setting ones have the next highest strengths. In the case of calcium chloride accelerated mixes those that set fastest are also the strongest.

USES OF FLOW-SET METHOD.

Probably the chief use of this method of making time-of-set determinations of concrete will be in investigational work in concrete to determine the effect of various factors on set. It is also capable of being applied practically. This is shown by the following example:

A floor was being laid, and a 1 : 2 mortar topping accelerated by using a calcium-chloride solution for gaging liquid was used for one portion, while the rest was laid with mortar gaged with plain water. Flow set determinations were made and the opinion of the finishers was obtained. This test brought out the fact that a mortar of a flow of about 190 could be wood-floated, while when it had a flow of about 140 it was in about the right condition to finish with a steel trowel. Once these flow constants were determined for the table and mold used, preliminary tests could determine very closely the time at which floating and finishing could be begun.

There is a certain minimum consistency or flowability of concrete that can be used for certain purposes, such as in a reinforced concrete building, and the length of time that the concrete retains a flowability greater than the minimum can be determined by the flow method.

Undoubtedly this method of measuring time of set can be applied to measuring the rate of stiffening of limes, plasters, clays, etc., and other plastic materials.

OTHER FACTORS AFFECTING SET.

Factors other than those that have been investigated undoubtedly affect the time of set.

The kind of aggregate, depending largely on its absorptive properties, will probably be found to influence the setting. Concretes made of absorptive clay, slag, and stone aggregate will probably set faster than similar concrete made of non-absorptive quartz aggregates.

Similarly, the moisture condition of the aggregate will tend to affect the set of the concrete. Wet aggregate will probably make the setting relatively slower, while dry aggregate will probably accelerate it slightly.

The gradation of the aggregate, the fineness of the sand and the relative amount of coarse aggregates may have some effect on set, and this is a field for future study. The change in setting time caused by the addition of different salts, admixtures and proprietary compounds may be determined by the method described.

It is believed that humidity has little effect on set, although no correlated data are presented on this factor. It should be noted that the whole test specimen is used in the flow-set test, and that for that reason, surface drying caused by low humidity probably does not materially affect the result. Humidity probably does affect the results of the Gillmore and Vicat methods of determining the time of set of neat cement as these tests are made on the surface rather than the body of the test specimen.

Acknowledgment.—It is desired to acknowledge the aid of Mr. G. M. Williams' preliminary work in developing the flow table which was the necessary antecedent of this work, and to give credit to Mr. R. A. Sherman for careful assistance in the carrying out of the tests.

DISCUSSION.

Mr. Cloyd M. Chapman.—Why did you discontinue the readings of the 22-per-cent test when the inclination of the curve continues uniform between the two-hour and three-hour points? The two, two and a half, and three-hour points are on a straight line; why not continue readings until the curve flattens out? **Mr. Chapman.**

Mr. Watson Davis.—Well, in reality, when the curve reaches a flow of 105, that is practically the time of set. That point is taken as the practical point of no flow because there is little difference between a flow of 100 and 105, and the measurement of that difference is difficult. **Mr. Davis.**

Mr. D. A. Abrams.—It seems to me that Mr. Davis has presented a valuable report and has described a method that has possibilities for the study of early hardening of concrete. There are one or two points that I wish to discuss briefly. Some of the diagrams are rather misleading, in that the lines are drawn from the initial ordinate straight to the next point. I am quite sure that those lines do not represent what happened in the tests. In other words, the curves should drop down rather sharply and then swing off to the other part of the diagram. This probably applies to all the diagrams in the paper. **Mr. Abrams.**

The flow table should have more rigid supports than those shown in the photograph. We have made a great many tests with this apparatus and find that it is necessary to design it quite rigidly in order for it to withstand the severe shocks to which it is subjected in operation. Needless to say the base part or the anvil on which the drop occurs has a good deal to do with the flow. If the machine is not rigid the results will be very different from the case in which the machine is rigid.

I wonder if Mr. Davis has made a study of setting of concretes of different water contents, different mixtures, or different gradings of aggregate? We find that the water-ratio of the mixture is a very important factor and one which reflects quite closely the properties of the concrete so far as strength is concerned. It seems to me that a study of this relation may bring out features which are common to many of the diagrams which Mr. Davis has worked out on a different basis.

VARIATION IN THE EFFECT OF RODDING CONCRETE.

By F. E. Giesecke.

The results of previous tests have shown that the effects of rodding concrete probably vary with the composition or character of the concrete.

Since the University of Texas had undertaken to cooperate with Committee C-9 on Concrete and Concrete Aggregates by preparing one of the series (No. 201) outlined by the committee, it was decided to prepare the series in duplicate in order to study the effect of rodding on the several types of concrete represented in this series.

The series selected was the one employing sand and pebbles as the aggregate; the fineness moduli were, respectively, 3.48, 5.50, 6.00, and 6.50. The mixes were, by volume, 1:7, 1:5, and 1:3.5; and the relative consistencies were 0.90, 1.00, 1.10, and 1.25; combining these variables produced 48 types of concrete; five specimens were made of each type.

The materials for each cylinder were weighed separately and the concrete for each cylinder was mixed separately; but each pair of duplicate cylinders was made on the same day and under like conditions; the five specimens of any one type of concrete were made on five separate days.

All specimens of the original and of the duplicate series were rodded while the molds were being filled, in three layers approximately 4 in. in thickness, with a $\frac{5}{8}$-in. pointed steel rod, 24 in. long, which was pushed into each layer about 25 times.

The specimens of the duplicate series were, in addition, rodded five times at thirty-minute intervals, each rodding consisting of pushing the rod about 25 times into the concrete and allowing all water which came to the surface to escape.

All specimens of both series were prepared by Mr. F. L. Snodgrass, Laboratory Assistant; all calculations and all tests were made by Mr. H. R. Thomas, Testing Engineer, or under his supervision.

The ultimate compressive strength at 28 days was determined for each specimen; measurements of deformation were made on three specimens of each group of five.

The results of the tests are shown in Table I, which shows also the ratios of compressive strengths and of 25-per-cent moduli of elasticity of concrete rodded six times to those of concrete rodded once, for each of the 48 types of concrete represented in this series.

TABLE I.—SUMMARY OF RESULTS SHOWING EFFECTS OF RODDING CONCRETE.

Mix, by Volume.	Consistency.	Fineness Modulus.																							
		3.48						5.50						6.00						6.5					
		Weight of Concrete, lb. per cu. ft.	Yield, sacks per yard.	Compressive Strength, lb. per sq. in.	Ratio of Strengths.	25-Per-Cent Modulus of Elasticity, thous. lb. per sq. in.	Ratio of Moduli.	Weight of Concrete, lb. per cu. ft.	Yield, sacks per yard.	Compressive Strength, lb. per sq. in.	Ratio of Strengths.	25-Per-Cent Modulus of Elasticity, thous. lb. per sq. in.	Ratio of Moduli.	Weight of Concrete, lb. per cu. ft.	Yield, sacks per yard.	Compressive Strength, lb. per sq. in.	Ratio of Strengths.	25-Per-Cent Modulus of Elasticity, thous. lb. per sq. in.	Ratio of Moduli.	Weight of Concrete, lb. per cu. ft.	Yield, sacks per yard.	Compressive Strength, lb. per sq. in.	Ratio of Strengths.	25-Per-Cent Modulus of Elasticity, thous. lb. per sq. in.	Ratio of Moduli.
1 : 7..	0.90	132.4 138.1	3.77 3.85	489 707	1.45	1667 2256	1.35	146.1 148.6	3.88 3.99	1092 1808	1.66	3330 4723	1.42	148.8 151	3.92 4.01	1180 1954	1.66	3297 4400	1.33	150.2 150.8	4.16 4.19	1558 2060	1.32	3583 3950	1.10
	1.00	132.6 135.6	3.71 3.85	426 707	1.66	1755 2143	1.22	145.6 149.9	3.87 4.02	995 1696	1.71	2957 4267	1.44	148.3 151.9	3.89 4.03	920 1947	2.11	3067 3737	1.22	150.1 151	4.17 4.22	1324 1945	1.47	3885 4740	1.22
	1.10	133.9 137.5	3.70 3.85	389 623	1.61	1945 2197	1.43	145.7 149.1	3.80 3.98	700 1504	2.15	2424 4355	1.85	148.8 151.8	3.84 4.00	717 1708	2.38	2760 4073	1.48	150.5 152.4	4.13 4.21	1073 1625	1.51	3440 3670	1.07
	1.25	131.7 136 9	3.58 3.80	295 518	1.76	1185 2207	1.86	145.2 149	3.77 3.97	517 1172	2.27	2620 4037	1.54	147.1 152.2	3.84 4.00	580 1210	2.09	2743 3715	1.35	148.3 151.8	4.04 4.23	848 1329	1.57	3113 4603	1.48
1 : 5..	0.90	137.9 142.7	5.15 5.38	910 1338	1.47	3043 2678	0.88	148.1 150.6	5.29 5.42	2367 3240	1.37	4618 5117	1.11	150.8 152.6	5.43 5.51	3120 3995	1.28	5220 5790	1.11	150.9 152.9	5.61 5.73	2498 3286	1.32	4823 5037	1.04
	1.00	135.7 141.7	5.03 5.41	916 1370	1.50	2057 3730	1.81	147.5 150.7	5.23 5.43	2208 3181	1.44	3820 4717	1.24	150.1 152.6	5.38 5.52	2941 3585	1.22	4550 4927	1.13	150.1 152.6	5.55 5.71	1833 2855	1.56	4290 4707	1.10
	1.10	134.3 141	4.95 5.37	686 1293	1.75	1843 2783	1.51	146.9 150.1	5.19 5.35	2105 3032	1.48	4190 4797	1.15	149.6 152.2	5.34 5.49	2431 3615	1.49	4357 5060	1.16	149 152.4	5.45 5.66	1474 2376	1.61	3813 4327	1.13
	1.25	134.3 141.6	4.89 5.39	614 1044	1.70	1849 2537	1.37	146.5 150	5.14 5.43	1626 2622	1.61	3120 4640	1.49	149 151.8	5.29 5.47	1716 3038	1.77	4277 4373	1.02	148.8 152	5.37 5.67	1092 1867	1.71	3393 4343	1.28
1 3.5	0.90	140.8 143.9	7.17 7.43	2116 2854	1.35	3517 3963	1.13	148.3 150.1	7.27 7.36	3510 4294	1.19	4300 5103	1.19	150 151.9	7.27 7.38	3761 4483	1.19	5159 5485	1.06	151.3 152.4	7.57 7.61	4031 4493	1.11	5107 5190	1.02
	1.00	139.9 144.6	7.01 7.40	1990 2837	1.43	3787 4320	1.33	148.4 149.9	7.22 7.30	3518 4177	1.21	4563 5500	1.21	150.4 152.4	7.19 7.37	3619 4370	1.21	5185 5766	1.11	150.7 152.4	7.5 7.66	3749 4318	1.18	5167 5170	1.00
	1.10	138.1 144.4	6.87 7.41	1830 2526	1.38	3255 4317	1.33	147.7 150.5	7.12 7.31	3294 3894	1.08	4660 5013	1.08	149.4 151.7	7.16 7.32	3443 3936	1.18	4757 5036	1.06	149.4 152.2	7.44 7.74	2907 3688	1.27	3910 5273	1.35
	1.25	137.4 144.6	6.81 7.36	1432 2434	1.70	2337 4940	2.12	146.9 149.8	7.04 7.27	2548 3415	1.12	4477 4983	1.11	148.3 150.6	7.10 7.33	2864 3510	1.23	4327 4572	1.06	148.6 151.4	7.25 7.57	2132 3151	1.48	4400 4817	1.16

NOTE.—The weaker specimens were rodded once, namely, while the molds were being filled; the stronger specimens were rodded six times, namely, once while the molds were being filled and five times thereafter at thirty-minute intervals.

It is apparent from Table I that the five additional roddings produced additional strength in each case, that is, for each value of the fineness modulus, for each consistency, and for each degree of richness of the mix.

The range of increase in strength due to the five additional roddings shown in Table I is from 138 to 8 per cent; this increase in strength can, however, be studied to better advantage by means of Fig. 1, in which the compressive strength of concrete rodded once is plotted against that of the same concrete rodded six times. It is apparent from Fig. 1 that the increase in compressive strength due to the five additional roddings varies from about 100 to about 12.5 per cent and that it is about 50 per cent for 2000-lb. concrete.

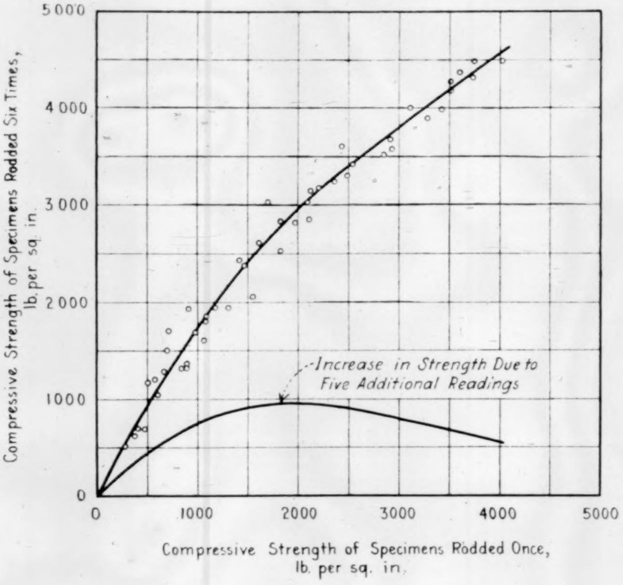


FIG. 1.—Relation of Compressive Strength of Concrete Rodded Once and Rodded Six Times.

The lower curve of Fig. 1 shows the interesting fact that the actual increase in strength was greatest in the 2000-lb. concrete.

In order to determine the actual increase in strength of thoroughly rodded over that of unrodded concrete it is necessary to take into account the increase in strength due to the one rodding which all specimens of these two series received while the molds were being filled.

A diagram (Fig. 2) of a paper presented by the author before the Society in 1920[1] indicates that the increase in strength due to the first rodding is about 30 per cent of that due to the next succeeding five roddings. The actual strengths from which this diagram was constructed are:

For no rodding, 1670, 1814, 1860; average 1781 lb. per sq. in.
For one rodding, 2580, 2280, 2040; " 2300 lb. "
For six roddings, 3750, 4020, 4076; " 3949 lb. "

Hence in that investigation the increase in strength due to the first rodding was 31.5 per cent of that due to the next succeeding five roddings.

If it is assumed that the effect of the first rodding is 30 per cent of that of the next succeeding five, it follows that the increase in the compressive strength of thoroughly rodded concrete over that of unrodded concrete, of the types considered in this investigation, will vary from about 185 per cent to about 17 per cent, and that it will be about 76 per cent for 2000-lb. concrete.

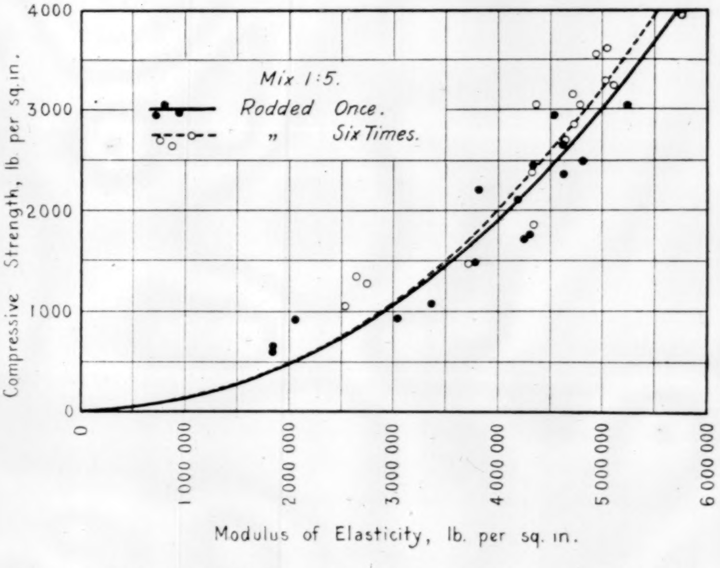


FIG. 2.—Relation of Modulus of Elasticity to Compressive Strength.

A careful study of the values shown in Table I shows:

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[1] *Proceedings*, Am. Soc. Test Mats., Vol. XX, Part II, p. 224 (1920).

1. That the increase in compressive strength due to rodding is greater for lean than for rich mixes, other factors remaining constant;

2. That it is usually, but not always, greater for wet than for dry mixes;

3. That its variation with the fineness modulus of the aggregate depends on the richness and on the consistency of the mix.

In studying the effect of rodding on the modulus of elasticity it was found difficult to determine the value of the tangent modulus accurately; for that reason it was decided to use the 25-per-cent secant modulus for comparison; but even that could not be determined as accurately as the ultimate compressive strength and for that reason there is a greater variation in the ratios of the moduli than in those of the compressive strengths.

The one ratio of 0.88, for example, shown in Table I, may be quite inaccurate because it is based on two widely differing values of the modulus (the value for the third specimen was discarded because it seemed too erratic).

It was also found that the richness of the mix had a considerable influence on the final modulus of elasticity.

For these reasons the moduli shown in Table I for 1 : 5 mix concrete were plotted in Fig. 2, in which the moduli are plotted against the strengths, for the specimens rodded once and for those rodded six times. The curves show clearly that the rate of increase of the modulus of elasticity due to rodding is about the same as the rate of increase in compressive strength due to rodding. With rich mixes, the rate of increase in modulus of elasticity, due to rodding is slightly less than the rate of increase in compressive strength.

WEAR TESTS OF CONCRETE.

BY DUFF A. ABRAMS.

INTRODUCTION.

The wide-spread use of concrete in the construction of roads, pavements and floors is one of the notable features of recent developments in this field.

During the past six years the Structural Materials Research Laboratory, Lewis Institute, Chicago, has carried out eleven different series of tests on the wear of concrete as affected by the following factors:

1. Method of conducting the test;
2. Quantity of mixing water;
3. Quantity of cement;
4. Grading of aggregate;
5. Grading of coarse aggregate;
6. Comparison of different fine aggregates;
7. Comparion of different coarse aggregates;
8. Hydrated lime and other powdered admixtures;
9. Relation of compressive strength to wear;
10. Age of concrete;
11. Time of mixing concrete;
12. Curing condition of concrete.

Wear tests were made in the Talbot-Jones rattler. The history of the development of the present wear tests and a brief bibliography were given in an earlier paper.[1] These investigations include tests of about 10,000 wear blocks and probably as many compression tests of concrete cylinders. The wear was measured by the thickness of concrete removed during the test; a low *wear* corresponds to a high *resistance* to wear.

OUTLINE OF TESTS.

In this paper principal consideration is given to the results of wear tests of concrete; it should be noted, however, that in practically all instances parallel compression tests were made. Concrete was hand-mixed except in Series 89. The general features of each series is given below:

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[1] Duff A. Abrams, "A Method of Making Wear Tests of Concrete," *Proceedings*, Am. Soc. Test. Mats., Vol. XVI, Part II (1916).

Series 45.—Studies of the method of making wear tests of concrete by means of the Talbot-Jones rattler; about 130 tests. These tests furnished the basis for our paper on "A Method of Making Wear Tests" referred to above.

Series 75.—A study of the effect of curing condition on the strength and wear of concrete; 1 : 4 mixture of sand with pebbles and crushed limestone as coarse aggregate. Tested at age of 3 months after storing for various periods in damp sand followed by air curing. Three hundred wear blocks. Details of tests were published in *Proceedings,* Am. Ry. Eng. Assn., 1919, and reprinted as *Bulletin 2* of this laboratory.

Series 89.—An investigation of the effect of time of machine mixing on the wear and strength of concrete; mix 1 : 4 with concrete of different consistencies and ages. About 200 wear blocks were tested. Details of tests were published in *Proceedings,* Am. Concrete Institute, 1918, p. 43.

Series 98.—A study of the size and grading of aggregate, kind of aggregate and quantity of cement on the wear and strength of concrete. The major portion of the tests was made on a 1 : 4 mixture using sand and pebbles. Tests were also made on (*a*) concrete from crushed limestone, granite and blast-furnace slag, as coarse aggregate; (*b*) 1 : 4 mix using pebbles of 21 different gradings; (*c*) 9 different mixtures ranging from 1 : 6 to neat cement, using a single grading of each of the four aggregates named above; (*d*) wear tests on concrete made of both limestone and pebbles, at ages ranging from 21 days to 6 months. A total of 1780 wear blocks were tested in this series.

Series 114.—This series comprised primarily a study of the effect of hydrated lime on the *strength* of concrete for a wide range of mixtures, consistencies, ages and curing conditions. Wear tests were also made on 1 : 4 concrete, relative consistency 1.10, and for 10 different gradings of sand and pebble aggregate. Three hundred wear blocks were tested. For details see *Proceedings,* Am. Soc. Test. Mats., Vol. XX, Part II, p. 173 (1920).

Series 129.—An investigation of the effect of variations in the rattler charge on wear of concrete. The total weight and the relative proportions of cast-iron balls of three different diameters were varied over a wide range; 790 wear blocks were tested.

Series 130.—The major portion of this series was a study of the effect of hydrated lime and various other powdered admixtures on the *strength* of concrete. Wear tests were also made on mixtures ranging from 1 : 4½ to 1 : 2½, using hydrated lime and five other powdered materials in varying quantities up to 33 per cent of the volume of cement; 500 wear blocks. Details were reported in *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part II, p. 176 (1920).

Series 133.—Preliminary investigations of the concrete-making properties of several lots of fine and coarse aggregates; 150 wear tests. These were routine tests to bring out the relative merits of different aggregate.

Series 134.—An investigation of the strength and wearing properties of concrete mixtures suitable for the wearing surface of concrete floors. The influence of size and grading of the aggregate, type of aggregate, cement and water constant, and curing conditions were investigated. Tests were made at age of 3 months. About 2800 wear blocks were tested.

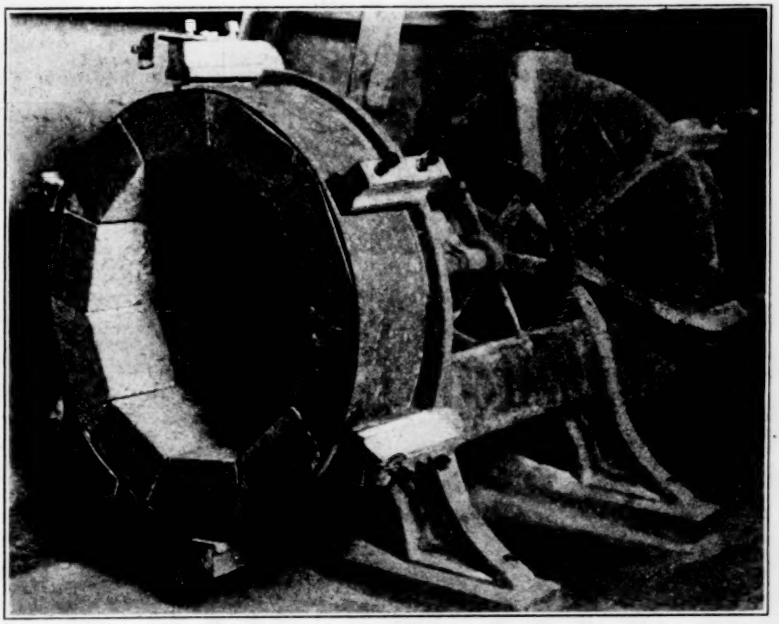

FIG. 1.—Talbot-Jones Rattler.

Concrete wear blocks 8 by 8 by 5 in. in place ready for closing test chamber. Machine has two heads so that duplicate tests can be made in same run.

Series 135.—An investigation of the concrete-making properties as determined by strength and wear of concrete from about 150 different samples of coarse aggregates collected from widely scattered sources. These materials included 28 samples of pebbles, 35 crushed limestone, 15 crushed granites, 11 traps, 13 sandstones, 24 blast-furnace slags and 45 miscellaneous samples. The coarse aggregates were separated into three sizes and recombined to one of three different gradings. The same sand and cement, and concrete of the same plasticity was used with each coarse aggregate. This series consisted of tests of about 1400 wear blocks and several thousand compression and miscellaneous tests. Details of this series are not given in this report; however, a summary of the principal tests made with coarse aggregates of "Grading A" is given in Table I.

TABLE I.—WEAR AND COMPRESSION TESTS OF CONCRETE MADE FROM MISCELLANEOUS COARSE AGGREGATES.

Wear tests of 8 by 8 by 5-in. concrete blocks made in Talbot-Jones rattler.

Comprssion tests of 6 by 12-in. cylinders.

Mix 1 : 4 by volume of mixed aggregate; approximately same as 1 : 2 : 3 mix.

Relative consistency 1.10; about the same as should be used in the construction of concrete roads to be finished by hand.

Hand-mixed concrete; one specimen to a batch.

Cement: a mixture of five brands purchased in Chicago.

Sand from Elgin, Ill., graded 0 to No. 4, used as fine aggregate in all tests.

Each coarse aggregate was screened and recombined to the following grading: No. 4 to ⅜-in., 25 per cent, ⅜ to ¾-in., 50 per cent, ¾ to 1½-in., 25 per cent by volume.

For each aggregate sample, the value for wear was the average of 10 tests and for strength, 5 tests, made on 5 different days.

Specimens stored in damp condition 14 days, then in air until tested at age of 3 months.

Coarse Aggregate.					Concrete Tests[1] (3 months).	
Kind.	Number of Samples Tested.	Unit weight, lb. per cu. ft.	Apparent Specific Gravity.	Absorption at 3 hr., per cent by weight.	Compressive Strength, lb. per sq. in.	Depth of Wear, in.
Pebbles	24	102	2.56	1.17	4330	0.51
Crushed Limestone	26	91	2.59	1.14	4560	0.44
Crushed Granite	12	92	2.59	0.32	4350	0.34
Crushed Trap	6	95	2.85	0.12	4210	0.40
Crushed Sandstone	7	86	2.34	3.94	4470	0.45
Crushed Slag	13	88	2.34	2.20	4240	0.48
Crushed Flint	2	83	2.43	....	4850	0.46
Crushed Marble	1	96	2.69	0.39	4620	0.42
Crushed Lava Rock	1	90	2.62	2.50	5350	0.40
Crushed Tufa	1	47	1.27	27.50	1960	0.66
Crushed Fire Brick	1	70	1.92	4.55	5390	0.43
Cement Clinker	2	88	2.22	8.20	5160	0.37
Boiler Cinders	1	40	1.51	8.70	3000	0.85

[1] Strength tests were also made at ages of 7 and 28 days, and 1 year on many of the aggregates.

Series 145.—An investigation of the concrete and mortar-making qualities of about 200 fine aggregates as determined by strength and wear tests of concrete. In collecting these samples special care was taken to secure materials of inferior quality or of unusual characteristics. The same coarse aggregate (pebbles) and the same quantity of cement and the same relative consistency were used throughout. This series consisted of about 1500 wear blocks as well as several thousand compression tests of concrete cylinders, etc. Details of this series are not given in this report.

MATERIALS, TEST PIECES AND METHODS OF TESTING.

The cement used consisted of equal parts of four or five brands of Portland cement purchased in Chicago. In general the aggregates were sand and pebbles of limestone origin from the Elgin, Ill., pit of the Chicago Gravel Co. In a number of the tests artificial gradings of these materials were used in studying the effect of size and grading of aggregates. In certain series aggregate from widely scattered sources were used. All concrete was mixed with water from Lake Michigan.

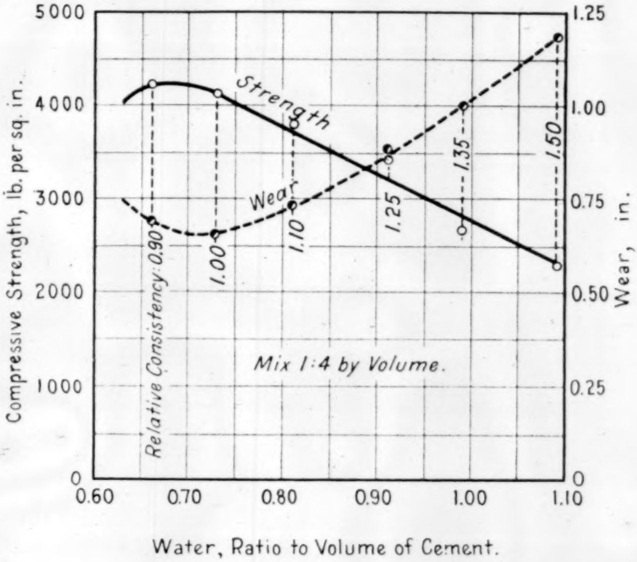

FIG. 2.—Effect of Quantity of Mixing Water on Wear and Strength of Concrete. (Series 75.)

Wear tests of 8 by 8 by 5-in. blocks and compression tests of 6 by 12-in. cylinders. Hand-mixed concrete.

In general the aggregate was sand and pebbles, graded up to $1\frac{1}{2}$ in. For one curing condition crushed limestone was also used as coarse aggregate.

Tests for 4 curing conditions were averaged. Each value for wear is average of 50 tests, for strength 20 tests.

Age at test, 4 months.

Reproduced from "Effect of Curing Condition on the Wear and Strength of Concrete" by Duff A. Abrams, *Proceedings*, Am. Ry. Eng. Assn., Vol. 20 (1919).

In this paper concrete mixtures are expressed as one volume of cement to a given number of volumes of aggregate *mixed as used;* 94 lb. of cement was considered to be 1 cu. ft. A 1 : 4 mix with aggregates graded up to $1\frac{1}{2}$ in. was most frequently used; this corresponds closely to 1 : 2 : 3 or 1 : 1½ : 3 mixtures commonly specified for one-course concrete road construction.

The quantity of mixing water is generally expressed in terms of the "relative consistency" of the concrete. A relative consistency of 1.00 requires such a quantity of water that a freshly molded 6 by 12-in. cylinder will slump ½ to 1 in. upon removal of the form by a steady upward pull. A relative consistency of 1.10 indicates the use of 10 per cent more water than required for a relative consistency of 1.00. The quantity of mixing water is also expressed by the "water-ratio," or the ratio of volume of water to volume of cement in the batch.

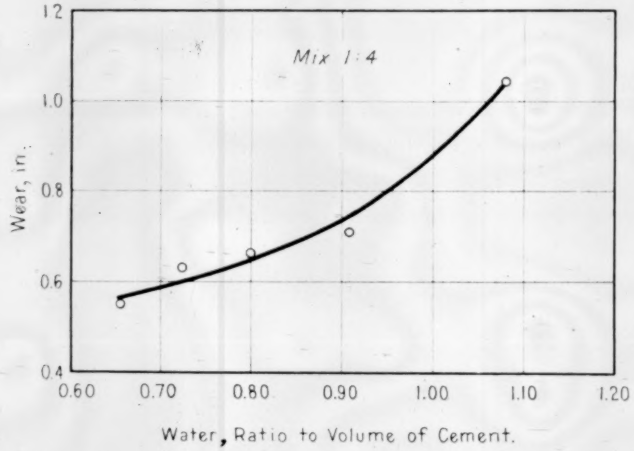

FIG. 3.—Effect of Quantity of Mixing Water on Wear and Strength of Concrete. (Series 89.)

Aggregate: sand and pebbles graded up to 1½ in.

Machine-mixed concrete. Each value is average of 30 tests from 6 mixing periods ranging from 15 seconds to 10 minutes.

Specimens stored in damp sand until 2 days prior to testing at age of 2 months.

Reproduced from "Effect of Time of Mixing on the Strength and Wear of Concrete," by Duff A. Abrams, *Proceedings*, Am. Concrete Inst., 1918, p. 38.

The "fineness modulus" is used as a measure of the size and grading of the aggregate. This value is the sum of the percentages in the sieve analysis divided by 100, and the sieve analyses are expressed as percentages coarser than each sieve.[1] A high value of fineness modulus represents a coarse aggregate and a low value a fine aggregate.[2]

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[1] See Tentative Method of Test for Sieve Analysis of Aggregates for Concrete (Serial Designation: C 41 – 21 T) of the American Society for Testing Materials, p. 586.

[2] For a discussion of the relation of water-ratio and fineness modulus to the strength of concrete see "Design of Concrete Mixtures," by Duff A. Abrams, *Bulletin 1*, Structural Materials Research Laboratory.

Wear tests were made on concrete blocks 8 in. square and 5 in. thick. In general, each wear block or cylinder was made from a separate batch of concrete mixed by hand in a shallow metal pan; in Series 89 machine-mixed concrete was used. Wear blocks were molded in metal forms which were set on a sheet of building paper placed directly on the concrete floor. The forms were filled with concrete and puddled about 25 times with a $\frac{5}{8}$-in. round steel rod pointed at the lower end. More concrete was then placed on the top and leveled off with a trowel. After about 2 hours the tops of the blocks were finished by hand with a wood float. The blocks were allowed to remain in the forms over night; during this period the tops were covered with damp cloths or building paper and damp

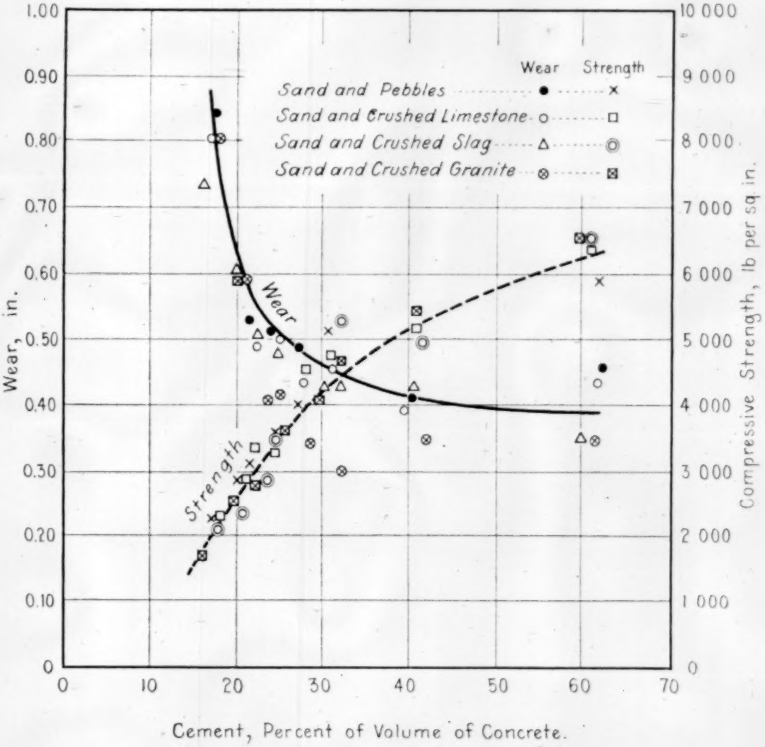


FIG. 4.—Effect of Quantity of Cement on Wear and Strength of Concrete. (Series 98.)

Hand-mixed concrete; relative consistency 1.10.
Each value for wear is average of 10 tests; for strength 2 tests.
Specimens stored in damp sand 14 days; remainder in air.
Age at test, 3 months.

sand. Upon removal of the forms the blocks were stored 14 days in damp sand or in a moist room and the remainder in the open air of the laboratory. Tests were generally made at the age of 3 months; variations in the method of storage and age at tests are noted on the diagram.

In general, the blocks for each condition were tested in sets of 10, 5 each on 2 different days. Our present practice is to make the specimens in sets of 10, 2 each on 5 different days.

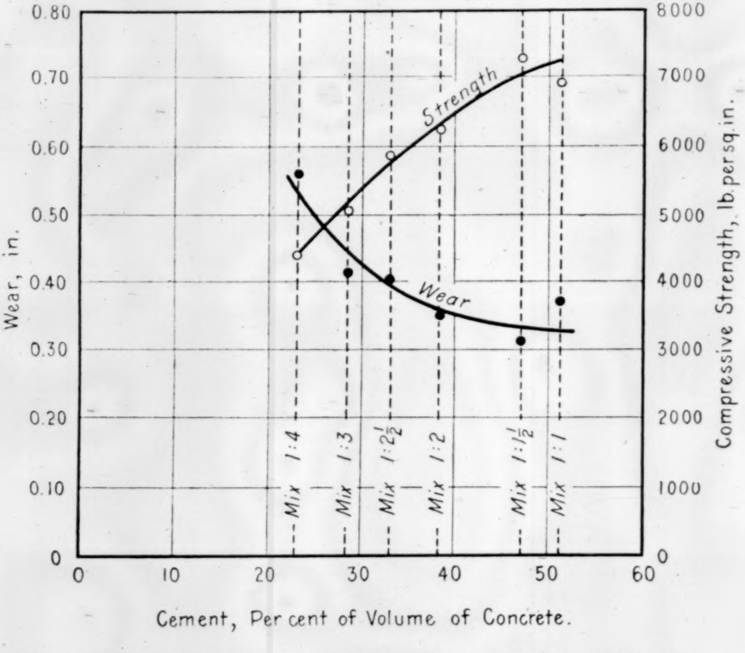


FIG. 5.—Effect of Quantity of Cement on Wear and Strength of Concrete. (Series 134.)

Hand-mixed concrete; relative consistency 1.10.

Aggregate: sand and pebbles from Elgin, Ill.

Each value for wear is the average of 40 tests, and of strength 16 tests. The values for 4 sizes of aggregates ranging from 0 to No. 4 sand to 0 to 1½-in. aggregate were averaged. The specimens for each condition were made on two different days.

Specimens stored in damp sand 14 days, remainder in air. Age at test, 3 months.

Wear tests were made in the Talbot-Jones rattler. This machine consists essentially of a heavy cast-iron head 36 in. in diameter with projective arms for holding the ring of test blocks. The head is rigidly attached to a horizontal shaft and suitable gearing is provided. The test blocks were arranged in a 10-sided polygon inside a heavy circular band and set in the machine head. The front of the chamber was then closed with a steel plate, and an abrasive charge of cast-iron balls placed in the chamber. The wear was produced by revolving the machine and subjecting the finished surfaces of the blocks to the tumbling action and impact of the balls. Our standard practice is to use 10 $3\frac{3}{4}$-in. balls and about 135 $1\frac{7}{8}$-in. balls, a total weight of 200 lb. The machine is run for 1800 revolutions at about 30 r.p.m.— 900 in one direction and 900 in the other. In two series of tests the total weight and the relative proportions of different sizes of shot in the charge and the number of revolutions were varied. In these tests an intermediate size of shot was also used.

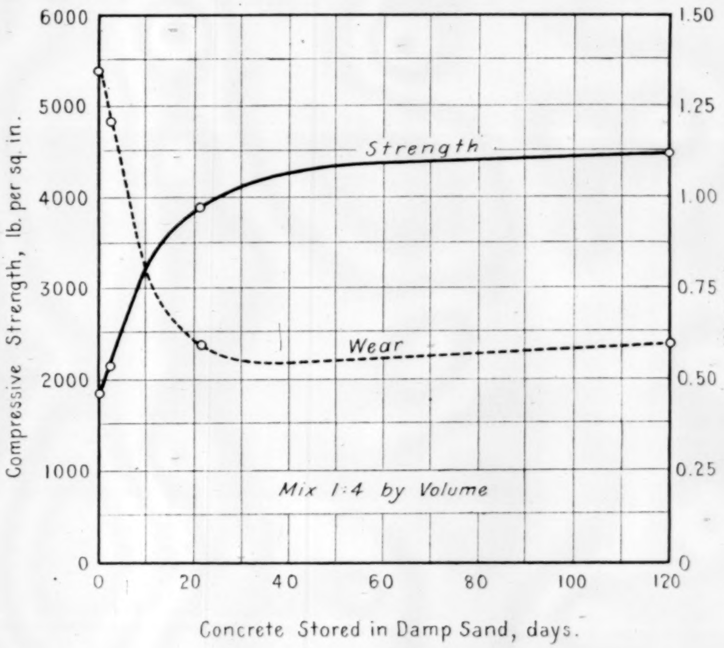


FIG. 6.—Effect of Curing Condition on Wear and Strength of Concrete. (Series 75.)

Note that all tests were made at age of 4 months. The upward trend of the wear curve at the 120-day storage period is due to testing these blocks in a damp condition. Compare Fig. 7.

Each value for wear is the average of 60 tests (10 each for 6 consistencies), of strength, 24 tests.

Aggregate: sand and pebbles from Elgin, Ill., graded 0 to 1½ in.

Reproduced from "Effect of Curing Condition on the Wear and Strength of Concrete," by Duff A. Abrams, *Proceedings*, Am. Ry. Eng. Assn., Vol. 20 (1919).

The blocks were weighed before and after test. The loss in weight, calculated to the average thickness of concrete removed by the test, was taken as a measure of the wear.

Fig. 1 shows the Talbot-Jones rattler with the blocks in place ready for the chamber to be closed. This machine is provided with two heads.

Parallel concrete specimens (6 by 12-in. cylinders) were generally made for compression tests at the same time as the wear blocks. The concrete was puddled into the steel forms in 3 equal layers. Three or four hours after molding, the top of each cylinder was capped by means of neat cement paste and a piece of plate glass.

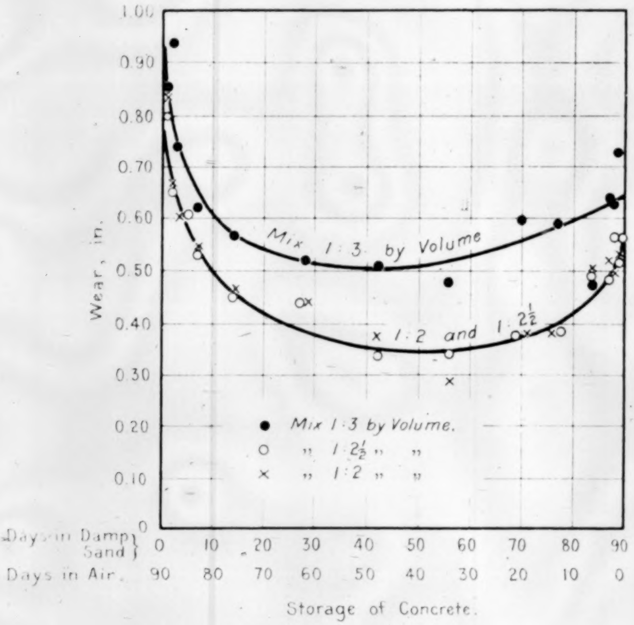


FIG. 7.—Effect of Curing Condition on Wear and Strength of Concrete Floor Mixtures.

(Series 134.)

Note that all tests were made at age of 3 months. The upward trend of the curve is on account of tests being made with blocks in a damp condition. Compare Fig. 6.

Relative consistency of concrete, 1.10.

Aggregate: sand and pebbles from Elgin, Ill., graded 0 to ⅜ in.

Each value for wear is the average of 10 tests and for strength, 4 tests, made on 2 different days.

TEST DATA.

In these investigations about 10,000 wear tests have been made. Due to the large mass of data, we can present in this paper only typical results from the most significant groups of tests. These values are presented in Table I and in diagrammatic form in Figs.

2 to 17. The most important conditions surrounding the tests are indicated in the notes which accompany each figure.

DISCUSSION OF TESTS.

The following notes indicate the principal features of the wear tests which have thus far been carried out.

Method of Conducting Tests.—After a study of methods of making wear tests, the Talbot-Jones rattler was adopted. The details of the test method are given above. In standardizing this test an investigation was carried out in which the total weight of cast-iron balls, as well as the relative proportions of balls of three different sizes were varied over a very wide range. Greatest wear was produced by the largest balls. The effect of number of revolutions was also studied; 3000 revolutions gave a wear of about 88 per cent higher than the standard test of 1800 revolutions. The test procedure selected as standard is adapted to a wide range of quality of concrete. A high-grade concrete will show a wear of about ½ in.; a poor concrete may lose as much as 1½ to 2 in. This test gives a combined abrasion

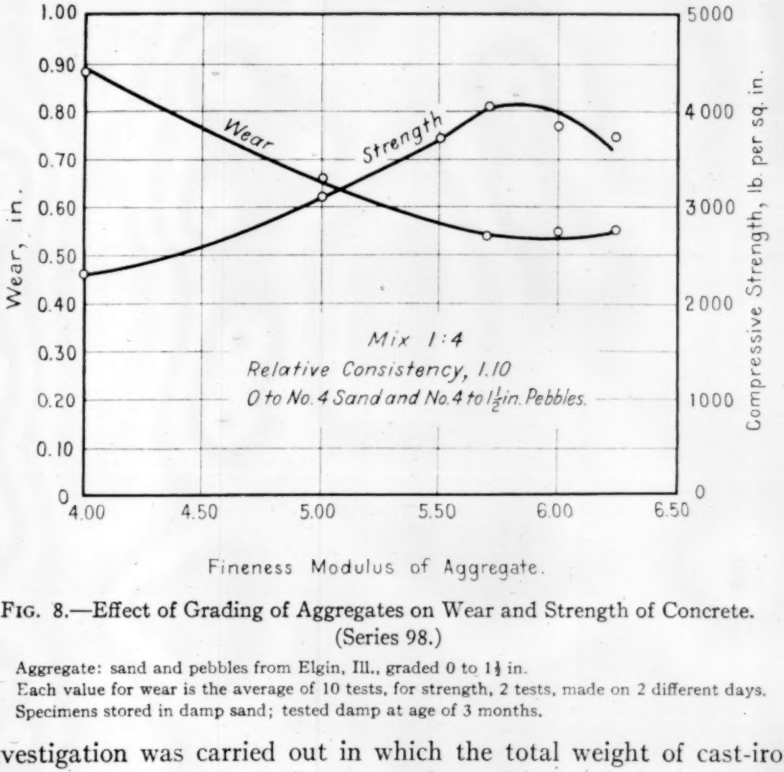
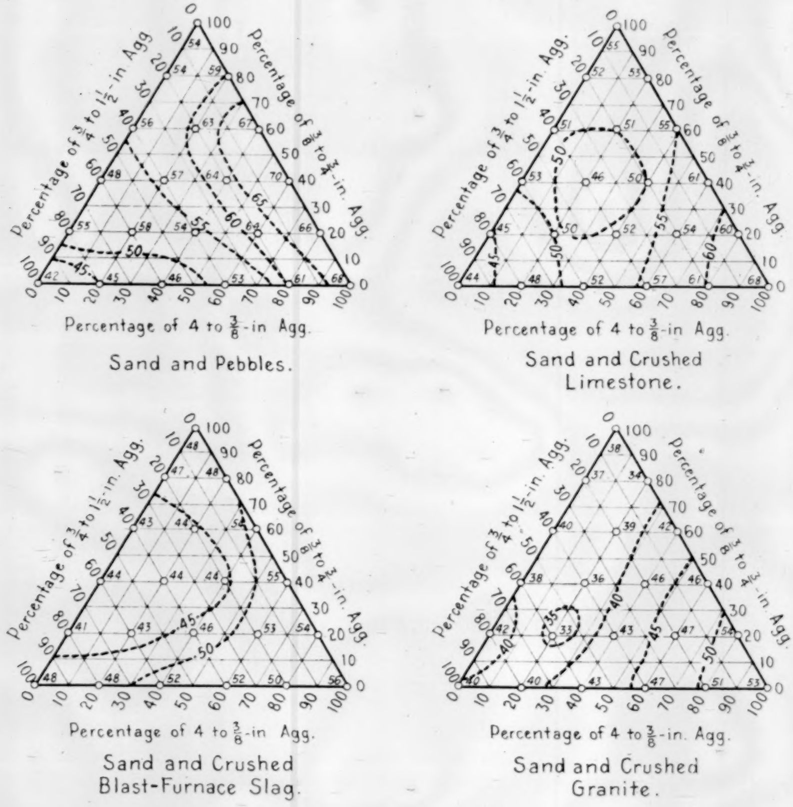


FIG. 8.—Effect of Grading of Aggregates on Wear and Strength of Concrete. (Series 98.)

Aggregate: sand and pebbles from Elgin, Ill., graded 0 to 1½ in.
Each value for wear is the average of 10 tests, for strength, 2 tests, made on 2 different days.
Specimens stored in damp sand; tested damp at age of 3 months.

and impact action which is not dissimilar to the treatment a concrete surface received under modern traffic. The advantages of this test as compared with other methods which have been used were pointed out in our paper on "A Method of Making Wear Tests of Concrete."



Sand and Pebbles.

Sand and Crushed Limestone.

Sand and Crushed Blast-Furnace Slag.

Sand and Crushed Granite.

VALUES OF WEAR GIVEN IN 0.01-IN.

Fig. 9.—Effect of Grading of Coarse Aggregate on Wear of Concrete. (Series 98.)

Mix 1 : 4 by volume. Relative consistency of concrete, 1.10.
Each value for wear is the average of 10 tests made on 2 different days.
Specimens stored in damp sand 14 days; remainder in air.
Age at test, 3 months.

Effect of Quantity of Mixing Water.—The effect of quantity of mixing water on the wear of concrete is shown in Figs. 2 and 3. In these diagrams variation in water content is expressed in terms of the water-ratio, or the ratio of the volume of water to the volume of cement in the batch. A water-ratio of 0.80 represents about the consistency which should be aimed at in road construction. Increasing this to 1.00 caused an increase in wear from 0.65 to 0.90 in. In other words, the wear increases rapidly with an increase in the quantity of mixing water. These diagrams confirm the conclusion of many other investigations carried out in this laboratory in showing the primary importance of restricting mixing water to the smallest quantity that will produce a plastic, workable concrete. It will be noted from Fig. 2 that the strength curve is almost opposite in form from the wear curve.

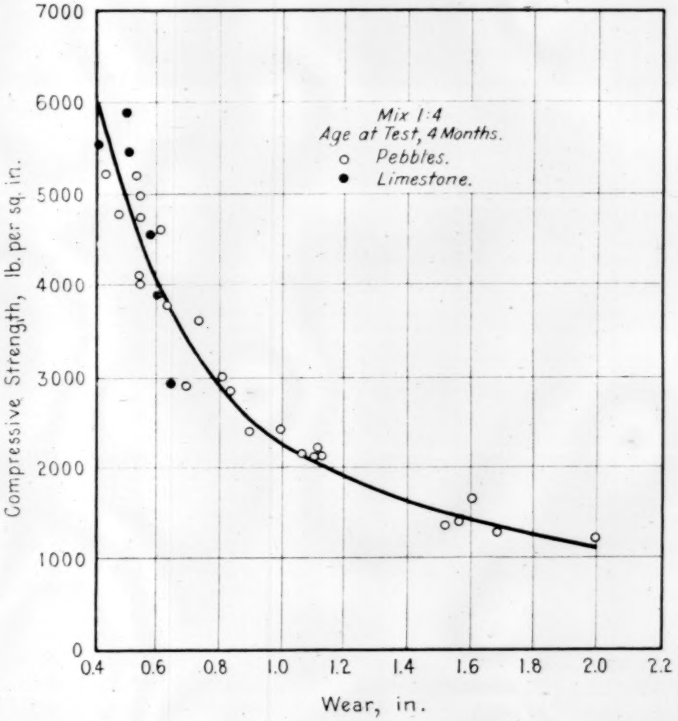


FIG. 10.—Relation Between Wear and Strength of Concrete. (Series 75.)

Aggregate: sand and pebbles, and sand and crushed limestone, graded up to 1½ in.

Each value for wear is the average of 10 tests and for strength, 4 tests made on 2 different days.

Tests for 4 conditions of curing and 6 consistencies are included.

Reproduced from "Effect of Curing Condition on the Wear and Strength of Concrete," by Duff A. Abrams, *Proceedings*, Am. Ry. Eng. Assn., Vol. 2 (1919).

Effect of Quantity of Cement is shown in Figs. 4 and 5. In Fig. 4 the mixtures ranged from 1 : 6 to 1 : 1, using pebbles, crushed limestone, granite and slag as coarse aggregates. In Fig. 5 mixtures ranging from 1 : 4 to 1 : 1 were used, with sand and pebbles as aggregate. All tests were made at age of 3 months after curing specimens for 14 days in damp sand and remainder in air. The wear decreased rapidly with the increase in quantity of cement used. It will be noted that here also the strength and wear curves are nearly opposite in form.

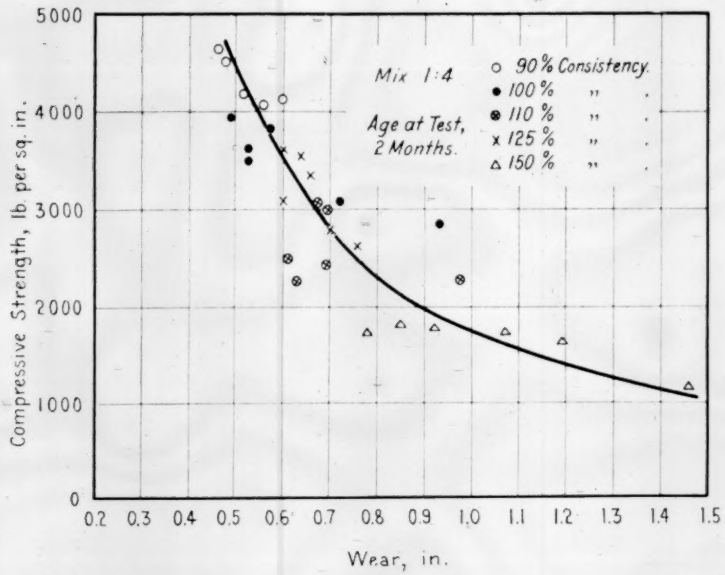


FIG. 11.—Relation Between Wear and Strength of Concrete.
(Series 89.)

Machine-mixed concrete; tests from 6 different times of mixing varying from 15 seconds to 10 minutes are included.

Aggregate: sand and pebbles from Elgin, Ill., graded 0 to 1½ in.

Specimens stored in damp sand until 2 days prior to test at age of 2 months.

Each value for wear is average of 5 tests, for strength, 4 tests, from the same batch.

Reproduced from "Effect of Time of Mixing on the Strength and Wear of Concrete," by Duff A. Abrams, *Proceedings*, Am. Concrete Inst., 1918, p. 38. Compare Fig. 3.

Effect of Curing Condition of Concrete is shown in Figs. 6 and 7. Fig. 6 indicates the importance of curing the concrete for a few days in a damp condition before it is subjected to wear. A curing period of 10 days reduced the wear from 1.4 to 0.8 in. Tests were made at the age of 4 months. The wear for all conditions in Fig. 6 is abnormally high, due to the fact that tests from a number of different consistencies were averaged. All tests in Fig. 7 were made at the age of 3 months, the relative periods of damp sand and air storage being varied. For the 1 : 3 mixture the wear was reduced from about 0.95 in. to 0.60 in. by curing for 10 days in damp sand. The upward trend of the curves at the right probably resulted from the specimens being tested before they were thoroughly dry, indicating that wet concrete is more affected by wear than similar concrete in a dry condition.

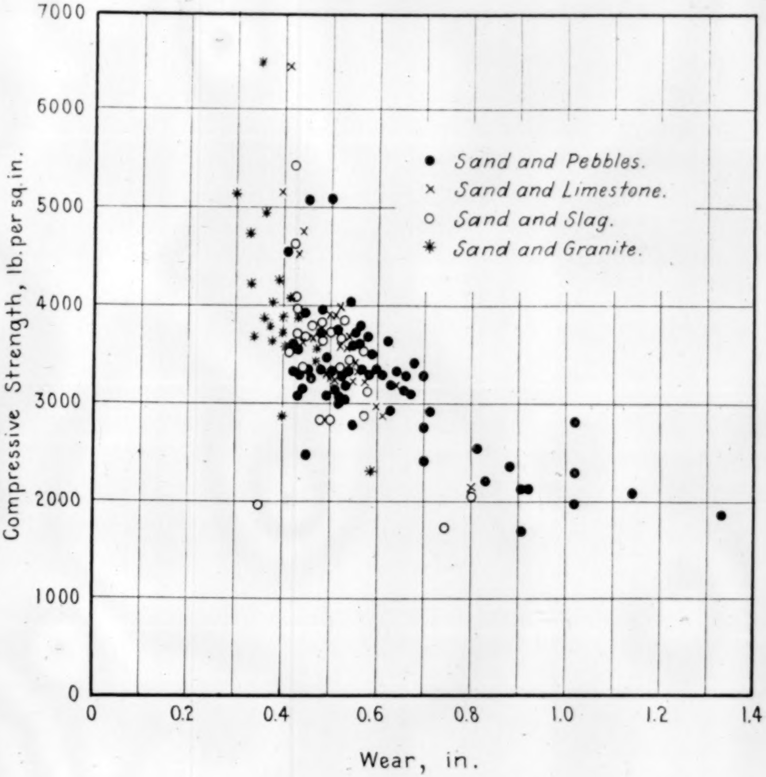


FIG. 12.—Relation Between Wear and Strength of Concrete. (Series 98.)

Hand-mixed concrete; relative consistency, 1.10.
Tests are included for a wide range in size and grading of aggregate and quantity of cement.
Specimens stored 14 days in damp sand; remainder in air. Age at test, 3 months.
Each value for wear is average of 10 tests; strength, 2 tests.

Effect of Grading of Aggregates is shown in Fig. 8. In these tests a 1 : 4 mix of the same consistency was used throughout; the size and grading of the aggregates being varied over a wide range by using different proportions of sand and pebbles. The variation in grading is indicated by the fineness modulus[1] of the aggregate, which is the sum of the percentages coarser than the sieves in the standard set. The aggregate of fineness modulus 4.00 was made up of 75 per cent sand and 25 per cent pebbles, that with fineness modulus of 6.00 was made up of 25 per cent sand and 75 per cent pebbles, etc.

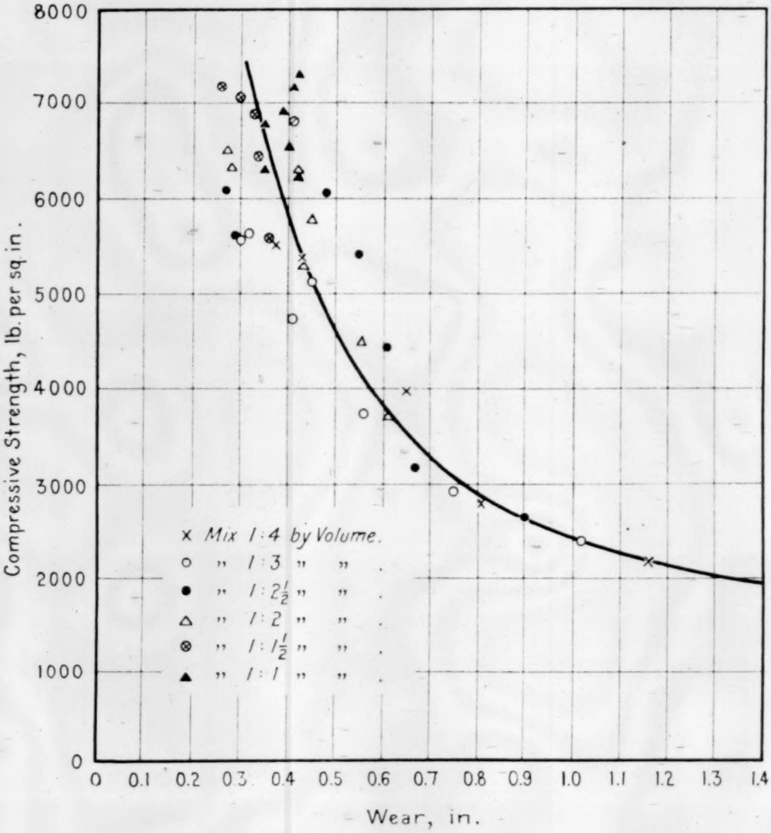


FIG. 13.—Relation Between Wear and Strength of Concrete. (Series 134.)

Hand-mixed concrete; relative consistency, 1.10.
Aggregate: sand and pebbles from Elgin, Ill.
Each value for wear is average of 10 tests; strength, 4 tests.
Tests include aggregates ranging in size from 0 to No. 28 sieve to 0 to 1½ in.
Specimens stored in damp sand 14 days; remainder in air.
Age at test, 3 months.

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[1] See " Design of Concrete Mixtures," by Duff A. Abrams, *Bulletin 1*, Structural Materials Research Laboratory.

The wear was materially reduced as the aggregates having a fineness modulus of 5.50 to 6.00 (a well-graded aggregate up to $1\frac{1}{2}$ in.) were reached. All tests presented in Fig. 8 were made on sand and pebbles of limestone origin. In this series, as in Figs. 2, 4, 5, and 6, the wear curve is almost exactly opposite in form from the strength curve.

Effect of Grading of Coarse Aggregates.—The principal results of the tests with coarse aggregates of different gradings (Series 98) are shown in Fig. 9. Pebbles, crushed limestone, granite and blast-furnace slag were each used in 21 different gradings. A well-graded sand was used throughout as fine aggregate. The gradings of coarse aggregate are indicated in Fig. 9 by the coordinates of the points on the triangles. Each point represents a definite combination of

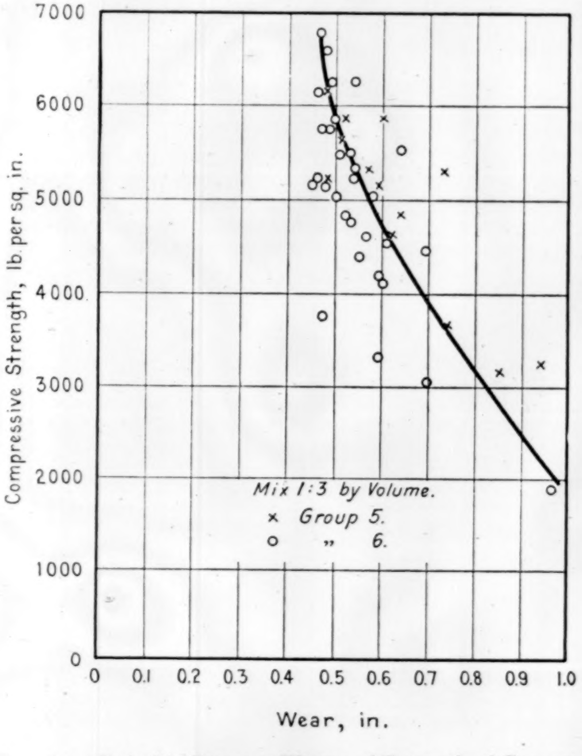

FIG. 14.—Relation Between Wear and Strength of Concrete.
(Series 134.)

Hand-mixed concrete; relative consistency, 1.10.
Aggregate: sand and pebbles from Elgin, Ill., graded 0 to $\frac{3}{4}$ in.
Each value for wear is average of 10 tests, for strength, 4 tests.
Tests are included for 3 mixtures and a wide range of periods of storage in damp sand and air.

the three sizes into which the coarse aggregates were screened. The contours of these diagrams show the wear of the concrete in hundredths of inches and indicate that the grading of the coarse aggregate may vary over a wide range without materially affecting the wear. This figure also shows the relation between the wearing qualities of concrete produced by these four types of aggregates. It should be stated that all of these aggregates were of high grade. The average wear for 21 gradings were as follows: pebbles 0.57 in., crushed limestone 0.53 in., slag 0.46 in., granite 0.42 in. The compressive strength of 6 by 12-in. cylinders made and tested under the same conditions were: pebbles 3360, crushed limestone 3520, slag 3580, and granite

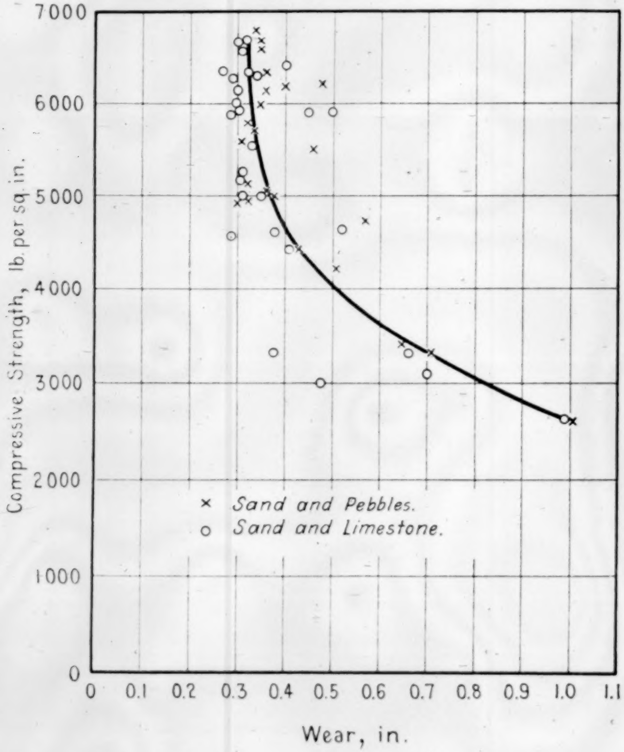

FIG. 15.—Relation Between Wear and Strength of Concrete. (Series 134.)

Hand-mixed concrete; relative consistency 1.10. Aggregate graded 0 to 1½ in.
Each value for wear is the average of 10 tests and for strength 4 tests made on 2 different days.
Tests are included for a wide range in sand content and for 4 mixtures.
Specimens stored in damp sand 14 days; remainder in air.
Age at test, 3 months.

3660 lb. per sq. in. All tests were made at the age of 3 months. Each value for wear is the average of 210 tests; for strength 105 tests. The relations between wear and strength for the same aggregates are shown in Fig. 12. This figure also includes concretes of mixtures ranging from 1 : 6 to 1 : 1. In comparing the above concrete strengths with those in Table I it should be noted that in the latter case coarse aggregates were of *coarser grading* than the average in Fig. 9.

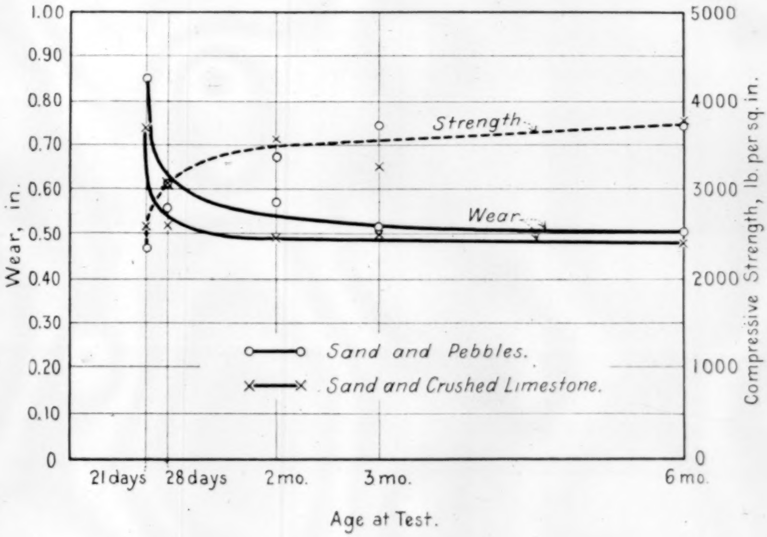

FIG. 16.—Effect of Age on Wear and Strength of Concrete. (Series 98.)

Hand-mixed concrete.
Mix 1 : 4 by volume; relative consistency, 1.10.
Aggregate: sand and pebbles from Elgin, Ill., graded up to 1½ in.
Each value for wear is average of 5 tests and for strength 2 tests, made on same day.
Specimens stored in damp sand 14 days; remainder in air.

Comparison of Different Coarse Aggregates.—Data on the relative merits of pebbles, crushed limestone, granite and slag were referred to in discussing Figs. 4 and 9. A comparison between pebbles of limestone origin and crushed limestone was made also in Series 75 and 134; see Figs. 10 and 15.

In Series 135, tests were made on about 150 samples of coarse aggregates from widely scattered sources. The principal results from tests made on coarse aggregates of "Grading A" are given in Table I. This grading was as follows: No. 4 to ⅜ in., 25 per cent, ⅜ to ¾ in., 50 per cent, ¾ to 1½ in., 25 per cent by volume. The wide variety of these samples will be seen when it is stated that the pebbles averaged in Table I were from 13, and the crushed limestone from 11 different states. It appears that the wear of concrete is not so much dependent on the qualities of the coarse aggregate used in the wearing surface as is commonly supposed.

It should be emphasized that in these tests all aggregates were of the same grading and care was taken to mix the concrete to as nearly as possible the same consistency. The general disregard of differences in grading of aggregates and consistency of concrete in comparing the concrete-making properties of different types of aggregates have led earlier investigators to the erroneous conclusion that there was a wider variation in strength of concrete from aggregates of the same type than for aggregates of different types. Our tests show a remarkable uniformity in the concrete strength of aggregates in a given class and much smaller discrepancies between the *different types* of aggregates than is usually supposed. Of the 24 samples of pebbles the lowest concrete strength was 3690 and the highest 4940 lb. per sq. in.—a maximum variation of 33 per cent; the *mean variation* from the average was only 4.8 per cent. The extreme values for wear were 0.74 and 0.44 in. It is notable that the extreme values for strength and wear were found in the same samples. In the case of the 26 crushed limestones the extreme values for strength were 4140

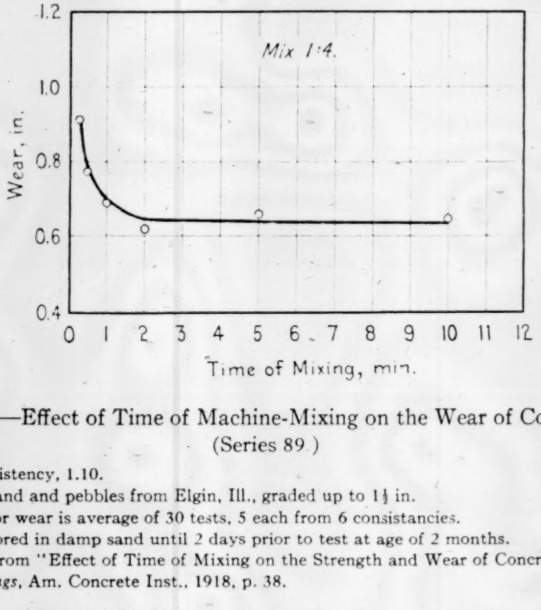

FIG. 17.—Effect of Time of Machine-Mixing on the Wear of Concrete. (Series 89.)

Relative consistency, 1.10.
Aggregate: sand and pebbles from Elgin, Ill., graded up to 1½ in.
Each value for wear is average of 30 tests, 5 each from 6 consistancies.
Specimens stored in damp sand until 2 days prior to test at age of 2 months.
Reproduced from "Effect of Time of Mixing on the Strength and Wear of Concrete," by Duff A. Abrams, *Proccedings*, Am. Concrete Inst., 1918, p. 38.

and 5020 lb. per sq. in., or a maximum variation of 21 per cent, and a *mean variation* from the average of 5.3 per cent. The wear for the limestone samples varied from 0.39 to 0.52 in. For the 12 granites, the extreme values for strength were 4130 and 4730 lb. per sq. in., or a maximum variation of 15 per cent, and a *mean variation* from the average of 2.9 per cent. Wear for granite varied from 0.30 to 0.41 in. For the 13 crushed blast-furnace slags the strength varied from 3600 to 4830 lb. per sq. in., or a maximum of 34 per cent, wear varied from 0.39 to 0.64 in., *mean variation* of 6.8 per cent.

These tests show little or no relation between the type of aggregate and the strength of concrete. Low strengths and high wear were given by tufa and cinders; highest concrete strength was found for fire brick, lava and flint; the wear for these samples was about the average. For the usual types of aggregates (pebbles, limestone, granite and trap) the concrete strength was quite uniform. Contrary to general opinion the sandstones gave strengths above the average. The strength of slag concrete compared favorably with the other materials, being about 4 per cent less than the average for pebbles, limestone, granite and trap. Granite showed the lowest wear of any group with a strength about the average of the usual types of aggregates.

Wear Tests with Miscellaneous Fine Aggregate.—A comparison of different fine aggregates was carried out in Series 145. It is not feasible to present the details of these tests; however, it may be stated that the wear of the concrete is, in general, not materially affected by the quality of the fine aggregate so long as it is structurally sound, clean and does not contain an excess of fine material. Further studies are now being carried out in order to bring out the relation between the wear of the concrete and the quality of fine aggregate.

Effect of Hydrated Lime and other Powdered Admixtures.—A complete report on the tests in which hydrated limes and other powdered admixtures were used was presented to the Society last year.[1] No details of these tests are given here. The wear of concrete was not sensibly increased by hydrated lime or other powdered admixtures used up to 20 per cent of the volume of cement.

Relations of Wear to Compressive Strength of Concrete.—In Figs. 2, 8, and 10 to 16, inclusive, the relation between the wear and the compressive strength of concrete is shown. All of these figures show a similar relation between wear and strength. In general, as the strength increased the wear decreased. As shown in an earlier paper[1] the relation between strength and wear of concrete may be represented by a curve of the form:

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[1] "Effect of Hydrated Lime and Other Powdered Admixtures in Concrete," *Proceedings*, Am. Soc. Test. Mats., Part II, p. 146 (1920). A report on a subsequent series of tests on the effect of hydrated lime will be found in *Bulletin 8*, Structural Materials Research Laboratory.

$$S=\frac{A}{W^n}$$

where S = the compressive strength of concrete,
W = the wear of concrete as determined by the Talbot-Jones rattler test,
A and n are constants depending on the quality of the concrete and the method of test. The constant A is the compressive strength of concrete which gives a wear of 1 in. by this method.

This relation appears to hold whether variations in strength are due to quantity of cement, size and grading of the aggregate, quantity of mixing water, age of concrete, curing condition of concrete, or other factors which affect the strength. This relation appears to be generally true also for aggregates of different types.

As an illustration of the values of these symbols, the equation for the curve in Fig. 10 is

$$S=\frac{2230}{W^{1.07}}$$

In this group a 1 : 4 mix was used and all tests were made at the age of 4 months.

Effect of Age on the Wear and Strength of Concrete are shown in Fig. 16. The tests in this series were made on blocks which were stored in damp sand 14 days and the remainder in the air of the laboratory. The wear shows a steady decrease with age, the strength a gradual increase, up to 6 months.

Effect of Time of Mixing Concrete.—The effect of time of mixing on the wear of concrete is shown in Fig. 17. The wear for all conditions on this curve is abnormally high due to the fact that a number of wet consistencies were averaged with other tests. The average wear decreased rapidly as the time of mixing increased from 15 second to 2 minutes.

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[1] "Effect of Curing Condition on the Wear and Strength of Concrete," by Duff A. Abrams, *Proceedings*, Am. Ry. Eng. Assn., Vol. 20, 1919 reprinted as *Bulletin 2*, Structural Materials Research Laboratory.

DISCUSSION.

Mr. Mattimore.

Mr. H. S. Mattimore.—May I ask a question in regard to the relation between the Wear Test and Compressive Strength as illustrated on the 0.6 line in Fig. 14? This seems to indicate that all the specimens noted on this vertical line are all of the same wear value, but there is a considerable difference in compressive strength running from 4000 to 6000 lb. per sq. in.

Mr. Abrams.

Mr. D. A. Abrams.—The points do not all fall exactly on a line, but I believe the line represents, as nearly as we can expect, the trend of the values.

Mr. Mattimore.

Mr. Mattimore.—My reason for calling attention to this relationship as illustrated on the curve is that I have found the same condition to occur when experimenting with Wear Test on a different type of machine. The general averages showed a relationship existing between Wear Test and Compressive Strength, but there were considerable variations in the individual tests. This, I consider, was due to the difference in grading and mineral composition.

Mr. Abrams.

Mr. Abrams.—There is no doubt that the physical condition of the aggregate has a bearing on the wear of the concrete in which it is used. We have just completed two large series of investigations along that line: in one series about 200 different samples of fine aggregate were used, in the other about 150 different lots of coarse aggregate were used in concrete. In general both compression and wear tests were made. Details of these tests are not given in this report, although the results are mentioned briefly. The tests have not been fully studied, but we are able to point out some of the most significant indications. In general, it may be said that the quality of the aggregate does not reflect itself so much in the wear of the concrete as we had formerly supposed. A wide range of aggregates, so far as their physical properties are concerned, will frequently give quite similar results in the wear test.

Mr. Crum.

Mr. R. W. Crum.—I might say that the corroboration of such experiments by actual construction is sometimes interesting. Last year we made wear tests in a manner practically similar to Mr. Abrams' on specimens made every day from concrete pavements, taken directly from the mixer in about fifteen different contracts. I think there were probably a thousand specimens tested altogether, and I am pleased

Mr. Crum. to say that the averages of our wear test would indicate that we had good concrete according to Mr. Abrams' figures, as the average wear on most of the jobs was under ½ in. and the others only slightly above ½ in. It would seem in concrete of that class, if the compressive strength is taken care of, that the wear will more or less take care of itself, and it is true, of course, that the actual wear on concrete pavements under rubber tire traffic is very slight. However, I think the wear test has a good deal of value in giving corroborative evidence.

Mr. Freeman. MR. J. E. FREEMAN.—It seems to me that these wear tests have a very important application in the finishing of concrete floors and their protection during the early hardening period. Most floors are enclosed in buildings and cannot, therefore, receive subsequently the additional moisture which naturally comes to surfaces of roads and sidewalks. Therefore, it is all the more important to see that by properly covering and wetting the floor surface during the early hardening period the moisture originally in the concrete is conserved and the surface is not allowed to dry out rapidly. Such protection should be provided for at least the first ten days, and longer if possible, in order to develop proper strength and the resistance to abrasion of which the material is capable.

Mr. Slater. MR. W. A. SLATER.—I should like to ask a question. If it is to be concluded, from the test results that have been given, that the loss by wear is inversely proportional to the strength of the concrete, and if it is also true that the loss by wear in pavements and buildings under the severest conditions is small in comparison with the loss by wear which is obtained in these rather exaggerated tests, is there any necessity for a continuation of wear tests? I should like to know whether we have gone far enough, whether we cannot forget about the wear test and say that the strength of the concrete is the gage of wear, sufficiently for the purposes required.

Mr. Abrams. MR. ABRAMS.—I am hoping we have gone far enough with wear tests so far as the main features of concrete making are concerned, that is, in studies of the variation of cement content, quantity of mixing water, grading of aggregates, curing conditions, etc. We have studied these factors thoroughly and I doubt if further tests will be necessary. There are, however, many topics which have not been studied, such as the effect of various compounds, different methods of handling concrete, etc. The question of the relative merits of different types of aggregates will probably require much further study.

Mr. Mattimore. MR. MATTIMORE.—The author has left me under the impression that the wear test is not necessary from the standpoint that the compressive strength is also an indication of the wear. I do not believe

Mr. Mattimore.

this is always the case, especially so, after study of a good many miles of concrete road. Some of these surfaces have a tendency to scale and have other defects, due to traffic stresses; what the final effect of this scaling is I am not prepared to say, but at least it is unsightly and such roads are subject to criticisms from the user. Probably it may be due to different methods of finishing, but I feel absolutely sure that in some cases it is due to certain types of fine aggregate. Now this fine aggregate when made into concrete shows a strong compression, but actual practice indicates that it does not resist the traffice wear as well as some other fine aggregates. Wear tests should be valuable to indicate such sands, and from that viewpoint I believe there is still a field for the wear test. It is not necessary to run wear tests on all combinations of aggregates in concrete, but I believe that they should be made on concrete where peculiar fine aggregates are used. This peculiarity may be in the grading or in the mineral composition.

Mr. Marcher.

MR. R. J. MARCHER.—Not being a member of the Society at present, I wish to apologize for asking the privilege of the floor, but inasmuch as I am here representing the New York State Highway Department I should like to say a few words. In the present discussion of how much value to place on concrete roads, Mr. Mattimore appears to have brought up a very important point in speaking of the excessively fine material in any aggregate floating to the top of the concrete and subsequently scaling off. Some years ago, when we placed a layer of bituminous material on newly laid concrete it peeled off, had the appearance of an elephant's hide, and much blame was laid to the different bituminous materials used; whereas the bituminous material stuck to the laitance (of cement and excess fine silt floating to the top of concrete from excess of water used), which cleaved from the concrete, leaving it pebbly and rough.

The gentlemen following Mr. Mattimore opportunely brought up the matter of local materials for road purposes not always being of as high a grade as that required by the abrasion test; and in this connection I feel impelled to call attention also to the use of materials in fine aggregates of concrete which may readily absorb water from the surface of the concrete pavement, then, freezing during the winter and being exposed to the action of the sun's rays and heat, causes destructive effects, at least to the surface of the concrete, one year after another. Too much observation and care cannot be given to this matter where sands resulting from argillaceous or aeronaceous shale, or shale stone only are available, notwithstanding the high breaking test resulting sometimes in such aeronaceous shale sands, or high abrasion test or French coefficient on such stone.

Mr. Kinney. MR. W. M. KINNEY. I agree with Mr. Abrams that the value of the wear test is somewhat less than was first believed. We are not so much concerned with the actual surface wear, which on a concrete pavement or floor is small, but what we are interested in is to avoid the wear which comes at the joints or at a crack which may occur due to lack of proper structural strength. A test to determine the surface wear is, therefore, not important since structural strength, and, therefore, freedom from cracks, is of more serious moment than wear resistance. Ordinarily smoothness or roughness determined by such a test would mean nothing in the pavement's riding qualities, in which evenness particularly at joints is of most importance.

Mr. Beyer. MR. ALBIN H. BEYER.—In view of the fact that some 7000 wear tests on concrete have been made by Mr. Abrams on a Talbot-Jones rattler, a type of machine not now in general use, and in order that these tests may be of more general value to the engineering profession, it would be desirable in my opinion to include in the summary of this paper, if possible, comparative wear tests made on other standard road materials such as granite blocks and paving brick. Unless this is done these wear tests on concrete will be of limited value only, as no standard of comparison has been established with other types of road materials.

Mr. Abrams. MR. ABRAMS.—We have not made tests on any material except concrete. However, three or four years ago we endeavored to secure samples of granite paving blocks. An association of block manufacturers were taking up the matter of furnishing the specimens, but, due to some changes in the organization or other causes, we did not get the blocks. In the discussion of my paper on "A Method of Making Wear Tests of Concrete," presented to the Society in 1916, G. P. Hemstreet described[1] a somewhat similar method of test which had been used by one of the asphalt block manufacturers. So far as I know the method has not been applied to other paving materials, except that as I stated earlier in my remarks, the machine was originally designed for tests of paving brick.

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[1] *Proceedings*, Am. Soc. Test. Mats., Vol. XVI, Part II, p. 203 (1916).

TESTING OF PLASTIC CALCINED MAGNESITE FOR USE IN OXYCHLORIDE CEMENTS.

By Max Y. Seaton.

The magnesium oxychloride industry dates from the discovery by Sorel, in 1867, of the cementing action of a mixture of magnesium oxide and a solution of magnesium chloride. Sorel found that the cement produced was enormously strong and had very high binding power, that is, that it would allow of dilution with a very large quantity of aggregate and still produce a product of high strength. It was particularly noted that it would bind sawdust in satisfactory fashion to a hard, tough mass. This could not be accomplished by any of the usual cementing mediums known at that time.

The exact chemical constitution of Sorel's cement is still an open question. It seems probable that it is only partly a definite oxychloride, probably $3\ MgO . MgCl_2 . 10\ H_2O$, and that this is mixed with solid solutions of indefinite composition. Efforts to regulate the composition of a mix in such fashion as to keep the oxide-chloride ratio constant at that which holds for some particular oxychloride have not been reflected by any striking results from a strength or soundness standpoint.

The commercial possibilities of Sorel's cement were very soon recognized and within a comparatively few years after his invention the construction of floors composed of sawdust, wood flour and sometimes silicious aggregate, cemented with magnesium oxychloride, became quite common in Germany and in France. Various difficulties in the preparation of satisfactory mixes were experienced, but the industry developed normally and later spread to this country. It is found possible to secure properties in a flooring using an oxychloride cement binder which cannot be obtained by the use of any other flooring material. The product, accordingly, has taken its place as a more or less standard building material. Oxychloride, or, as they are commonly called, "composition" floorings require highly skilled workmanship in their application, but numerous organizations are now in a position to lay such floors. The development of exterior stuccos in which magnesium oxychloride is the binding medium is more recent. Sorel's original statements as to the waterproofness of his cement have not been entirely confirmed and there was for a long time a real doubt as to the permanence of such stuccos. Experience has shown, however, that, provided the raw materials are of proper quality and are properly mixed, a sound and permanent stucco will result.

In the preparation of any oxychloride cement, three classes of raw materials are required; aggregates, magnesium chloride, and magnesium oxide. The aggregates employed include sand, ground sand or silex, marble or limestone dust, talc, china clay, sawdust and wood flours of various grades, asbestos fiber, and pulverized cork. The fineness and the percentage of voids in sand, the fineness of the various fine fillers, the type of wood and the particle size of wood flours and sawdust, the fiber length of asbestos, and the fineness of granulated cork give indications as to their value. The magnesium chloride employed is recovered from natural brines or salts in the Stassfurt district, or from Michigan, Utah, or California in this country. The usual product is either a solid or granular material containing in the neighborhood of 98 per cent $MgCl_2.6\ H_2O$ and less than 2 per cent of calcium chloride, of magnesium sulfate, or of sodium chloride. Chemical analysis clearly indicates its quality. The magnesium oxide required is essentially all prepared from natural magnesite, large deposits of which occur in Greece, Austria, Venezuela, and in the states of Nevada, Washington, and California. The term "plastic calcined magnesite" is in a sense a misnomer. Magnesite after being calcined is obviously no longer magnesite but is magnesium oxide or magnesia. Inasmuch as the magnesium oxide used by the oxychloride industry is generally prepared by the heating of natural magnesite rock, the term has gained such standing with consumers that it will be used unchanged throughout this paper. "Plastic magnesia" or "caustic magnesia" are occasionally employed in the same sense. The testing of this product has proved one of the most troublesome points encountered by producers of oxychloride cements.

PHYSICAL TESTS OF OXYCHLORIDE CEMENTS.

It is obvious, of course, that the value of any plastic calcined magnesite lies in its ability to form sound, strong, and permanent oxychloride cements when used in proper mixtures and that only tests which are indicative of its ability to fulfill this function will throw light on its quality. We must consider first, then, the question of physical tests of oxychloride cements.

Selection of a standard testing mix for oxychloride cement investigations is rather troublesome. Entirely unsatisfactory results have been obtained by attempting to test mortars containing only sand as an aggregate, that is, by following the general practice used in testing Portland cement. The reason for the trouble is not far to seek. The mortars and the concretes used in Portland cement tests approximate in composition mixes used in the field. It is quite rare for a commercial oxychloride cement to contain only sand as an aggregate, or at least only sand of the character of the sands usually used in cement testing. The usual oxychloride stucco is either prepared from an excessively fine sand or contains a considerable amount of fine aggregate, most commonly ground silica or silex. It is found, in fact, that best results can be obtained only when such a fine aggregate is used in an oxychloride mix. An elaborate series of investigations has indicated that most concordant test results are secured from a mix which contains as high as two parts of silex to five of sand. Such a mix requires the use of only a comparatively small amount of calcined magnesite, $12\frac{1}{2}$ per cent of the total mix being sufficient. The standard testing mix referred to throughout the balance of the paper will be one containing one part calcined magnesite, two of silex—the material known commercially as 120-mesh silex being used—and five of standard Ottawa sand. When the question of adoption of a standard floor mix is considered, even more difficulty is encountered. So many different types of floors are laid, varying from soft and resilient to hard and stonelike, that any one mix will represent but a comparatively small proportion of the total actual installations. There are definite relations between the results obtained on flooring and on stucco mixes when used with various magnesites, so we will consider at length only tests on the standard stucco mix.

The data necessary for determination of quality of an oxychloride cement can be obtained from tests for strength, volume change, setting time, and permanence of the product.

Strength Tests.—Four types of strength tests have been studied: namely, tensile, compressive, and cross-bending strengths, and resistance to abrasion. No particular comment is needed on tests for tensile or for compressive strengths. The ordinary standard size briquette for tensile tests and the usual cubes or cylinders employed for mortar compression tests can be used to good advantage. Such tests, although throwing much light on the properties of oxychloride cements, sometimes do not check field results. It should be recognized that oxychloride products are used at present only as comparatively thin surface coatings, never being employed in mass work of any type. Neither briquettes nor compression cubes or cylinders can be aged under conditions comparable with the aging of such thin coats of flooring or stucco. Especially during the early life of the cement, contact with air exerts a considerable influence on its rate of gain of strength.

It has been considered important, accordingly, to work mainly with test specimens approximating in shape a section from the coatings as applied in practice. Excellent results have been secured from flat bars $\frac{1}{2}$ in. thick, 2 in. wide, and 24 in. long. These bars can readily be prepared in suitable steel molds and, after proper aging, can be tested in a simple cross-bending machine in which the load is applied by running shot into a cup supported on the bar. An ordinary plasterers' trowel is used in preparing the test specimens and the influence of various methods of troweling can be readily studied. Flat bars of this type, besides more closely approximating field aging conditions for stucco or flooring mixes, allow also of determination of modulus of elasticity and of the making of water resistance tests, which latter cannot be conveniently made on other forms of specimen.

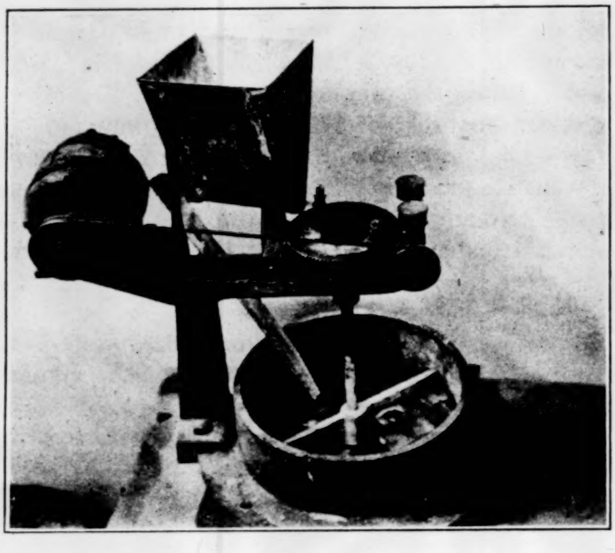

FIG. 1.—Abrasion Machine for Testing Composition Floors.

For flooring mixes, there is no inherent reason to suppose that a direct relation between tensile strength and resistance to abrasion need exist. Some interesting data on the abrasion resistance of various composition floors has been obtained by the apparatus shown in Fig. 1. This machine rotates a set of steel cubes weighing about 5000 g. over the surface of the floor while a slow stream of fine silex is fed onto the surface to serve as abrasive material. The depth of the impression in the floor is readily obtained from a small measuring bridge supported on points outside the abraded area by which a map of the floor surface can be drawn.

Volume Change.—The volume change, or more exactly, the linear expansion or contraction of a test specimen, is of decided importance in a study of oxychloride cement quality. Two methods for the measurement of this property have been considered. One consists in the preparation of bars 1 in. square and 10 in. long, which have metal plates imbedded in their ends. These bars can be removed from the molds at about the period of final set and measured by a large micrometer. Such bars, however, do not allow of determination of change in length during the early ages of the material, that is, during the period before final set, as they are too weak to be handled at such a time. Inasmuch as a certain amount of difficulty with cracking of stucco and of flooring mixtures has been encountered during this early period, somewhat more satisfactory results have been obtained by measurement with the Berry strain gage of the movement of reference points inserted in a $\frac{1}{2}$-in. bar of stucco or flooring mix which is formed on a sheet of waxed paper and need not be disturbed during testing. Such measurements can be begun at the period of initial set.

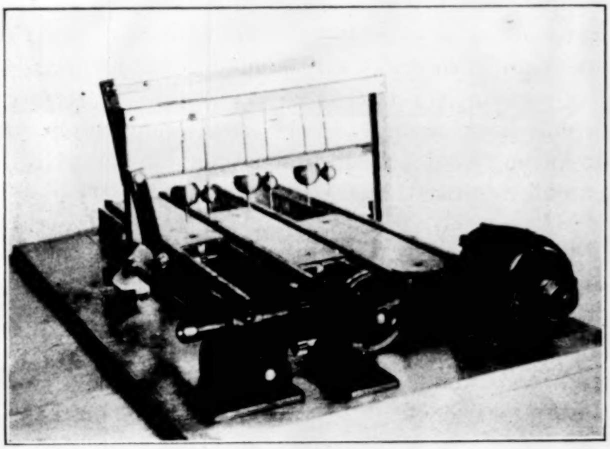

FIG. 2.—Hill Automatic Setting-Time Machine

Setting Time.—Setting time of oxychloride mixes can be determined by the usual Vicat or Gillmore needles. Certain complications are introduced by the fact that mixes containing aggregate must be tested. The results on neat mixes of calcined magnesite and magnesium chloride solution are not found to be comparable with results obtained from the use of the same magnesite in the usual flooring or stucco composition. Some difficulty in determining definitely the end point of setting time may be encountered on account of the presence of sand in the mixes being tested, but determinations are still fairly accurate. Where a large number of determinations are to be made, the Hill setting-time machine shown in Fig. 2, which automatically raises and lowers a set of Gillmore needles onto an extremely slowly moving pat of the oxychloride mix, has been found to give good results. With a known rate of movement of the pat, setting time can be determined by measuring the length of the series of impressions from each needle.

Permanence.—Inasmuch as all oxychloride products are submitted to periodic wetting either from the weather, in case of a stucco, or from scrubbing, in case of a flooring, some data on water resistance of oxychloride mixes is of value. The flat bars mentioned above allow of making a water test comparatively easily. They can be placed behind a perforated grid which protects their backs from direct contact with water and sprayed with a gentle mist of water directed against their faces. Strength can be determined after various periods of wetting and of subsequent drying. A satisfactory water test has been found to consist of spraying 14-day-old bars for three successive 24-hour periods with 24-hour drying periods intervening, finally testing the bars wet and after two days' additional drying in comparison with the usual test on an unsprayed bar.

FACTORS INFLUENCING THE PROPERTIES OF OXYCHLORIDE CEMENTS.

Various factors will influence the value of the test results obtained by any of the methods noted above.

Consistency of the mortar will influence strength in the same direction in which consistency variation influences strength of Portland cement mortars. The effect is very much less marked; however. With Portland cement mortars, an increase in consistency from normal to 125 per cent of normal gives a lowering in strength to about 65 per cent of normal. A similar increase in consistency of an oxychloride cement mortar gives a decrease in strength to 93 per cent of normal. There is not as great danger, accordingly, of poor results being obtained from excessive addition of chloride solution with oxychloride cements as there is from the use of too much water with Portland cement. On this account, too, the usual schemes of definition of aggregate quality which depend directly or indirectly on the amount of water required to make a plastic mix with the aggregate in question entirely fail when applied to oxychloride cement mixes.

The strength of the magnesium chloride solution has great influence on the properties of oxychloride cement. Fig. 3 gives the results obtained from an average oxychloride stucco mix by increasing the strength of magnesium chloride solution progressively. It is seen that satisfactory results cannot be expected from dilute chloride solutions.

The curves might indicate that better cements would be obtained as the specific gravity of the chloride solution was increased to a very high point. Other factors, however, must be studied before such a step can be considered. With chloride solution strengths above 24° Baumé, undue expansion effects develop. The optimum concentration of the magnesium chloride solution appears to lie at 22° Baumé. A certain amount of field work is done with chloride solutions of from 18° to 20° Baumé, but the slight saving in magnesium chloride effected by this practice cannot be justified in view of the decided advantage to be gained by the use of somewhat stronger chloride. The reason for the use of weak chloride is frequently said to be the fact that such chloride solutions will make an oxychloride cement which sets slower. This is entirely opposed to the results found from determination of setting time of a series of mixes in which chloride strength is varied. From the practical man's standpoint setting time of an oxychloride stucco is of interest inasmuch as it influences the behavior of the stucco when dry pebble dash is applied to it. A material which sets too fast resists the penetration of the pebbles. Careful tests have

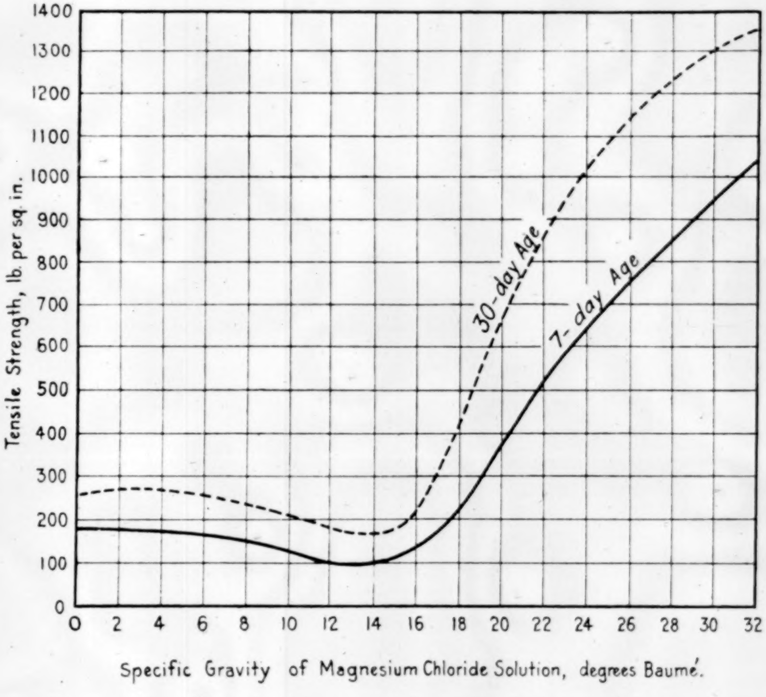

FIG. 3.—Relation Between Specific Gravity of Chloride Solution and Tensile Strength of 1 : 2 : 5 Oxychloride Mix.

shown that although there is a slight difference in favor of a stucco prepared with weak chloride when the question of dash penetration is considered, this difference is only in the neighborhood of 10 per cent, an amount which is not observable in actual practice. Observations of the application of oxychloride stucco in the field definitely confirm this statement.

The character of the aggregate influences the various properties of an oxychloride cement in a rather complex way, and the question can no more be covered in a short space than can that of the study of aggregates for use in Portland cement concretes. In general it may be said that the use of fine aggregate is essential for the attainment of high strengths and good water resistance. The mechanism of the setting reaction with oxychloride cement is quite different than with Portland cement. When Portland cement sets, the small particles surround themselves with a shell of reaction product but the center of each cement particle remains unchanged. In a sense, then, Portland cement furnishes its own fine aggregate. With oxychloride cements, provided the calcined magnesite is reasonably finely ground, each particle of magnesium oxide completely enters into reaction. If the reaction product is called on to fill the comparatively large voids between sand grains, a mass of inferior strength will result. However, if a fine aggregate is introduced which will itself enter the voids between sand grains, the oxychloride cement will need only to coat these particles of fine aggregate and to fill the much smaller voids which would result and much higher strengths and permanence will be secured. Here, as in the case of Portland cement mortars or concretes, the cementing material is the weakest portion of the set mass and if it can be reduced to a minimum, the physical properties resulting will be more desirable. When very fine magnesites are employed, the amount required for production of strong cements can be reduced to a surprisingly low figure, 4 or 5 per cent only being required in a mixture in which the coarsest aggregate is a comparatively fine sand. If an oxychloride concrete were to be formed, the amount needed would be still smaller. Curves giving strength of mixtures of various composition, in all of which the same magnesite and same strength of chloride solution were used, are given in Fig. 4. They indicate strikingly the advisability of the addition of fine aggregate. It should be noted that the influence of fine aggregate on wet strength is even greater than on dry strength. Mixes without fine aggregate often disintegrate completely on wetting.

Storage conditions during the aging of oxychloride test specimens of any type must be carefully regulated. Storage in air is always employed. The temperature must not vary more than 10° F. from a standard of 70° F. and humidity not over 15 per cent from a standard of 50 per cent relative humidity if concordant results are expected. High temperature or low humidity increases rate of gain of strength and greatly accelerates setting; low temperature and high humidity have the reverse effect.

The quality of commercial calcined magnesite exerts a tremendous influence on the properties of oxychloride cements. Certain magnesites appear on the market which will not give a satisfactory product no matter what attention be paid to other details of mix composition. The usual tests of magnesite quality which have been applied in the past have consisted of a chemical analysis of the calcined product. In general, limits for ignition loss, calcium oxide, silica and magnesium oxide have been written into specifications. Users of this product have come to realize during the past few years, however, that their chemical analysis specifications were not insuring them a magnesite of high quality. Some results which bear out this point are shown in Table I. Careful inspection of these figures will show that there is no relationship whatever between the chemical analysis and the strength or the permanence as indicated by the resistance to water of the cements produced from the various magnesites.

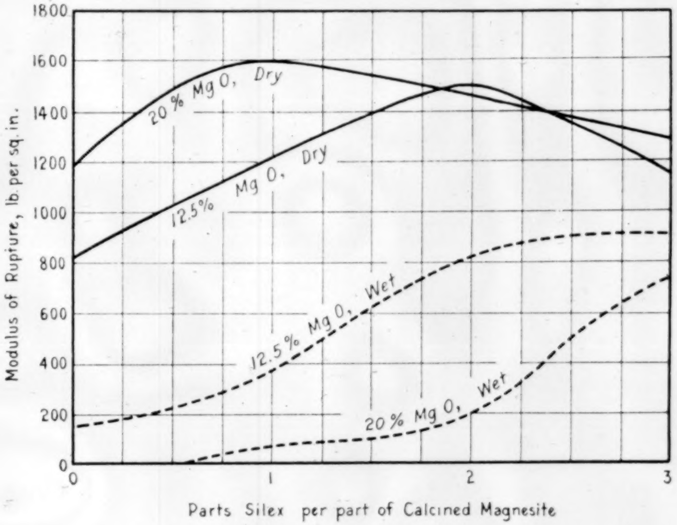

FIG. 4.—Strength at 14 Days of Oxychloride Mixes Containing Calcined Magnesite, Silex, and Sand. Ratio of Silex to Sand Varied, but MgO Content of Each Mix Held Constant.

Study of several hundred commercial magnesites has indicated that there is only one factor determinable by chemical test which exerts a definite influence on the character of the cement. This is the percentage of active lime, that is, the amount of calcium oxide, hydroxide, or basic carbonate which will react with magnesium chloride solution with the liberation of calcium chloride. The amount of this constituent present bears no relation to the content of total lime in the magnesium oxide. Active lime can be determined by agitation with dilute magnesium chloride solution and determination of the amount of calcium chloride introduced into the solution. Unfortunately, it is found that the relation between strength, permanency and active lime content is only traceable when average figures covering many magnesites are examined. Other factors play so important a part in regulating oxychloride cement strength that the relation does not appear when test results on individual samples are examined.

TABLE I.—COMPARISON OF CHEMICAL ANALYSIS OF CALCINED MAGNESITES AND PHYSICAL PROPERTIES OF OXYCHLORIDE CEMENTS.

1 : 2 : 5 Mix. 22° Baumé Chloride

Magnesite No.	Chemical Analysis (values in per cent).						Setting Time, hr. and min.		Modulus of Rupture, lb. per sq. in.		
	Loss on Ignition	CO_2	SiO_2	R_2O_3	CaO	MgO	Initial.	Final.	Dry.	Wet.	Recovered.
1......	9.20	4.05	9.58	0.95	7.50	73.7	2:15	3:00	1500	828	1218
2......	6.05	4.20	17.7	4.50	11.10	60.6	2:00	6:00	1362	654	1374
3......	8.35	3.25	5.07	0.80	3.58	82.0	2:30	4:30	1232	642	977
4......	6.98	1.68	7.01	0.42	3.64	82.8	3:45	4:30	1010	618	854
5......	10.65	4.07	8.09	1.32	4.34	75.6	2:15	4:00	1277	594	1188
6......	7.91	2.08	1.41	0.59	2.44	87.6	2:15	4:00	1580	525	967
7......	9.09	1.54	2.09	1.20	3.40	85.0	3:45	6:00	1486	273	605
8......	8.69	3.44	13.34	2.03	4.28	71.6	2:30	3:30	1011	252	810
9......	2.95	2.80	3.45	0.88	4.48	88.2	2:30	3:30	1604	132	198
10......	6.95	2.54	7.65	1.21	3.75	80.5	2:00	4:00	1378	97	300

The explanation of the wide discrepancy between chemical analysis and physical test results is found in the fact that the time-temperature history of the calcining procedure is of vital influence on the reaction between magnesium oxide and magnesium chloride, although it is not reflected in any major change in analysis. Widely varying results can be secured from samples of calcined magnesite prepared from the same natural rock burned until essentially all the gas is removed, and accordingly having approximately the same composition.

SUGGESTED SPECIFICATIONS.

Fairly satisfactory results can be obtained in study of magnesite quality if reliance be placed on purely physical tests. A determination of fineness is unquestionably of value. At least 97 per cent of the material should pass a 100-mesh screen and at least 75 per cent a

200-mesh screen. Calcined magnesite is a comparatively easy material to grind and it is very probable that this fineness can be greatly increased and quality accordingly improved without introducing serious manufacturing difficulties. Coarse magnesite results in abnormal expansion of the cements prepared from it. The magnesite, if of satisfactory fineness, should be used in a standard oxychloride mix, preferably the one magnesite, two silex, five sand composition previously mentioned, and further tests carried out on this material. The specific gravity of the chloride solution used should be 22° Baumé.

The plastic oxychloride mortar should not show initial set within an hour. It should attain final set within eight hours. A two-hour minimum for initial set is preferred by some workers while some will consider the eight-hour maximum for final set unduly long. The first limits, however, are about those met by average commercial calcined magnesite. Modulus of rupture on the flat bars previously described should be at least 550 lb. per sq. in. at one day and at least 1000 lb. per sq. in. at seven days.[1] Oxychloride cements from many magnesites will give figures much higher than these. Limits on expansion and contraction are exceedingly difficult to set but it is probable that a magnesite which shows over 0.3 per cent contraction or expansion within twenty-four hours after initial set in the mix specified should be considered as of questionable quality. Limits for water resistance are also hard to set. Unless the oxychloride cement made from a particular magnesite shows a wet strength after the standard spraying procedure of at least 30 per cent of its dry strength, however, some doubt as to magnesite quality should be felt.

A calcined magnesite which meets the requirements suggested will certainly be of at least average quality. Much better material than that indicated can be secured when greater attention to the preparation of the calcined product is given by the various producers. Cooperative work is now under way which should lead to the establishment of more definite limits for the various factors discussed, probably resulting in the issuance of definite specifications for plastic calcined magnesite within a year or so.

The oxychloride industry is one of remarkable latent possibilities. It has suffered seriously from lack of attention to the quality of the raw materials used and from lack of knowledge of the basic principles of mix preparation. As more data on both of these points become available, there is little question but that oxychloride cement products will take their place as standard construction materials for certain definite uses.

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[1] On ½ by 2-in. bars, broken on 20-in. centers, the modulus of rupture will average 2.8 times the tensile strength.

A METHOD OF DETERMINING THE TENSILE STRENGTH OF PORCELAIN.[1]

BY F. H. RIDDLE AND J. S. LAIRD.

Porcelain of constantly increasing strength and toughness is in demand as new uses of porcelain are developed and objects made of porcelain, such as high tension insulators, are used under service conditions of constantly increasing severity. Conditions of service determine whether strength to resist impact, abrasion, loading in compression, transversely, or in tension is required, and methods of testing should be devised accordingly. Thus, for spark plugs impact tests are most desirable, while for insulators used in tension, tensile tests should be used. Porcelain being a very brittle material, unsatisfactory methods of testing have given rise to the current belief that porcelain is variable and unreliable under tension loading and accordingly should be used only in compression. There is little to be found in the literature on this subject.

Friese[2] reports on the basis of tests with special test specimens, tensile strengths of 1300 to 2000 kg. per sq. cm., results which are undoubtedly much too high. Rosenthal and Singer[3] state that the tensile strength determination is attended with very great difficulty, and report 261 kg. per sq. cm. as the approximate strength of their insulator porcelain. The method described here is believed capable of furnishing reliable results, provided a sufficient number of specimens are tested to eliminate the occasional specimen of abnormally high or low strength which appears even in the most carefully prepared set of experiments.

APPARATUS USED.

Two types of test specimens have been devised, designed to eliminate as far as possible transverse stresses and excessive local stresses which would tend to produce shattering. Either of these specimens, having a minimum cross-section of 0.125 – 0.2 sq. in., may be broken in an ordinary 2000-lb. Olsen cement testing machine provided with special grips or clutches.

Test Specimen No. 1 has conical ends or shoulders which make an angle of about 15 deg. with the straight portion in the center (see Fig. 1). The test specimen T_1 is held by small steel clamps consisting of the split bushing B ground to fit the fired specimen and held by the collar C, the load being applied through the ball and socket joint by means of the plate P_1 held in slots in the jaws of the testing machine. A soft gasket *G* of blotting paper is inserted between the porcelain and the bushing to distribute the load, or else the porcelain will fail with a small load by splitting into thin disks. A fresh gasket is used with each specimen. Specimens of this type may be used either glazed or unglazed, but must be of uniform size and shape or they will not fit the clamps.

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[1] A contribution from the Research Laboratory of the Jeffery-Dewitt Co.

[2] Friese, "Das Porzellan als Isolier und Konstruktionsmaterial in der Elektrotechnik," p. 41.

[3] Rosenthal and Singer, *Keramische Rundschau*, Vol. 29, p. 81 (1921).

Test Specimen No. 2 is dumb-bell shaped, the diameter of the ends being about twice that of the reduced central portion (see Fig. 2). In testing, it is held by a split ring *R* with the same radius of curvature as the shoulders of the specimen. This ring fits into a recess in the plate P_2, which in turn is held in the slots in the jaws of the testing machine. No gasket is required with this piece if the shoulders are glazed, but satisfactory results have not been obtained with unglazed pieces even by using a gasket.

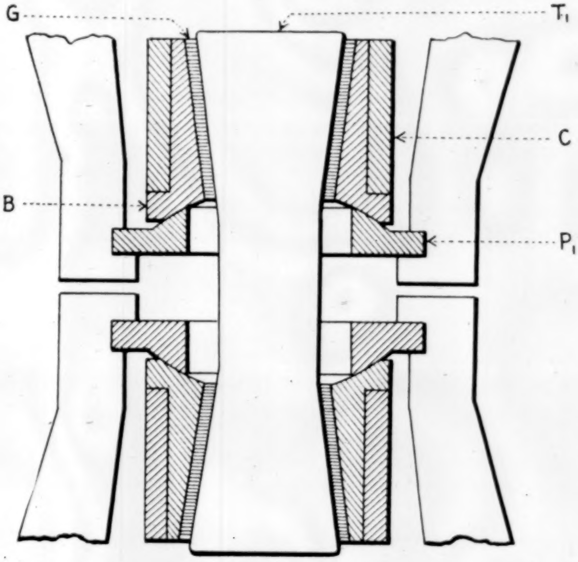

FIG. 1.—Porcelain Test Specimen with Conical Ends.

Of the two types, No. 1 appears to give slightly higher results; possibly on account of its shape it stands firing better. The second type requiring no gasket permits of more rapid manipulation, and is more satisfactory when there is any considerable variation in size or the pieces have warped in firing.

PREPARATION.

Test specimens have been prepared by pugging and extruding rolls of suitable size, throwing rolls by hand, and by cutting blanks from large pugged and cast blocks. It has been found that different strengths are shown by specimens prepared in different ways, and for comparative tests there must be strict adherence to one standard method of preparing the blanks. The blanks are turned in the green condition to such dimensions as will give fired specimens of standard size, shrinkage being determined and allowed for as in regular ceramic practice. The minimum cross-section of the fired specimens is determined by calipering and averaging a number, the variation from standard dimensions being kept within very narrow limits as it has been found that with specimens of about 0.2 sq. in. the calculated tensile strength increased about 0.5 per cent for a decrease in area of 1 per cent.

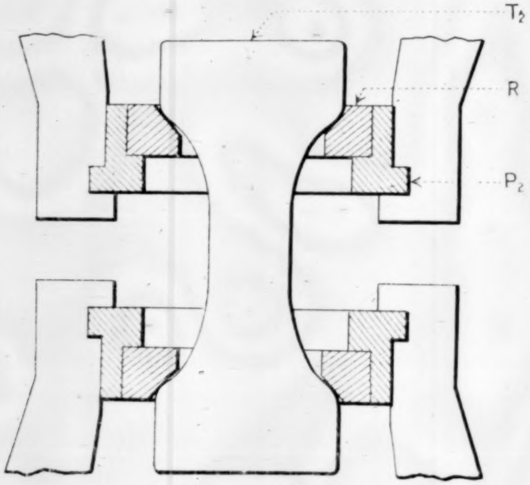

FIG. 2.—Porcelain Test Specimen, Dumb-Bell Shaped.

When dry, the shoulders of the specimens are glazed, the central portion of minimum cross-section being left free from glaze to avoid the effect of the glaze in increasing or decreasing the strength of the specimens. This glazing of the shoulders is necessary with specimens of the second type, and is employed with those of the first type for the sake of uniformity and to insure that failure occurs in testing in the central cross-section of the specimen.

The glazed test pieces are fired on end in saggers usually on a little placing sand or in clay bats. Completely covering the specimens with sand causes them to break in firing. The specimens are burned in the regular porcelain kilns (or where noted in special experimental kilns). Specimens which warp in firing give unreliable results and should be rejected.

RESULTS OBTAINED.

A large number of tests have been made with porcelain specimens prepared and tested as described above. The consistency shown by the results indicates that this method gives an accurate measurement of the relative strengths of different porcelains, agreeing with the results shown in using the porcelains on a commercial scale.

In a series of tests the average variation of a single determination from the mean of the series is 14 to 15 per cent, the maximum variation 30 to 40 per cent. It is therefore necessary to test 15 to 20 specimens to obtain a value reliable to a few per cent. This refers to porcelain which has been satisfactorily prepared and fired. Specimens which have been subjected to considerable variation in heat treatment, or have been subject to strains in forming so that they warp on firing are much less uniform.

TABLE I.—TENSILE PROPERTIES OF PORCELAIN.

Test Specimen.	Average Cross Section Area, sq. in.	Average Load, lb.	Average Strength, lb. per sq. in.	Average Variation, per cent.	Maximum Variation, per cent.
TRIAXIAL PORCELAIN.					
No. 1 (conical)	0.131	816	6 249	±15.0	±39.7
No. 2 (dumb-bell)	0.127	731	5 760	±15.6	—23.2
SPECIAL PORCELAIN.					
No. 1 (conical)	0.129	1320	10 250	±17.7	—37.9
No. 2 (dumb-bell)	0.130	1211	9 390	±15.1	—33.9

Table I gives the results of a typical series of tests, the specimen blanks being formed by pugging. About twenty specimens were tested in each set.

On the basis of the tests which have been made by this method we have determined that good triaxial porcelain has a strength of 3000 to 6000 lb. per sq. in., calculated from the breaking strength of specimens of 0.4 in. diameter. Special high temperature porcelains show strengths running up to 10,000 to 12,000 lb. per sq. in.

RATE OF APPLICATION OF LOAD.

It should be noted that with the type of testing machine employed in this test the jaws are not moved apart at a uniform rate, but the load is increased at an approximately uniform rate of about one thousand pounds in forty seconds. During the first part of a pull, while the specimen is seating itself and the gasket undergoing compression, it is a little difficult (and unnecessary) to keep the beam balanced. Later there is no difficulty up to the moment of failure.

EFFECT OF SIZE OF TEST PIECE ON CALCULATED TENSILE STRENGTH.

The tensile strength of porcelains as determined by these small specimens appears high compared with results obtained in practice with pieces of porcelain of larger cross-section.

In testing metals it has been found that higher tensile strength values are obtained with smaller specimens, particularly with brittle metals. This may be expected to be the case with porcelain for two reasons: (1) The larger the section the greater the difficulty in forming and firing, and the smaller the chance of obtaining uniform material free from flaws or strains and (2) The larger the specimen tested the greater the difficulty in avoiding unequal loading and the introduction of cross-bending or tortional stresses.

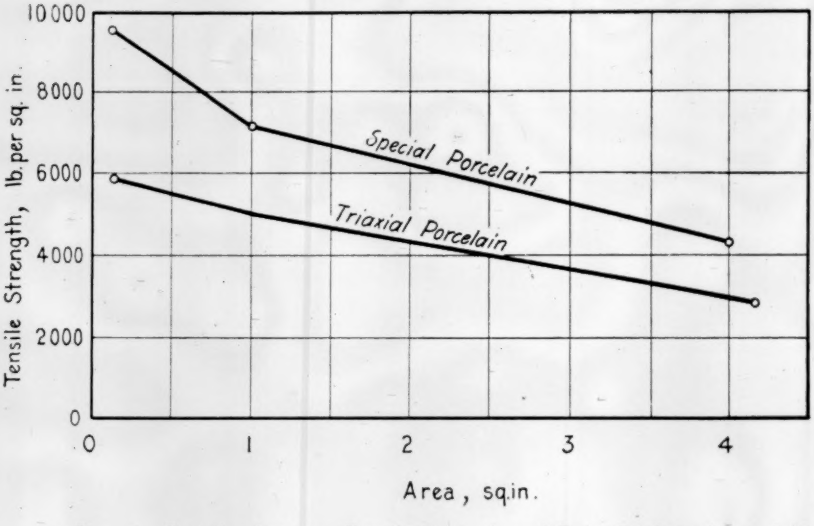

FIG. 3.—Relation between Tensile Strength and Cross-Section of Porcelain.

It is further possible that the tensile stresses cannot be distributed uniformly over the whole cross-section, but that the outer layers have to bear an undue amount of the stress.

In attempting to obtain some information with regard to these important questions, we prepared a number of test specimens somewhat similar in shape to the small conical specimens, but with minimum diameters after firing of 1.125 and 2.25 in. giving cross-sections of one and four square inches, respectively.

They were broken in a 5000-lb. Olsen machine, using special grips provided with a ball and socket device to avoid cross-bending stresses. In each test a lead gasket was inserted between the porcelain specimen and the steel grips. The preparation and testing of these larger specimens was rather difficult and time consuming so the data obtained are much less complete than is desirable.

The broken surfaces of the larger specimens are interesting as suggesting the mechanism of fracture. There is a smooth area of varying size usually more or less centrally located and almost always surrounding a flaw in the porcelain. Radiating from this area to the outside of the specimen are jagged broken grooves running at a slight angle to the cross-section. On putting two halves together, wedge-

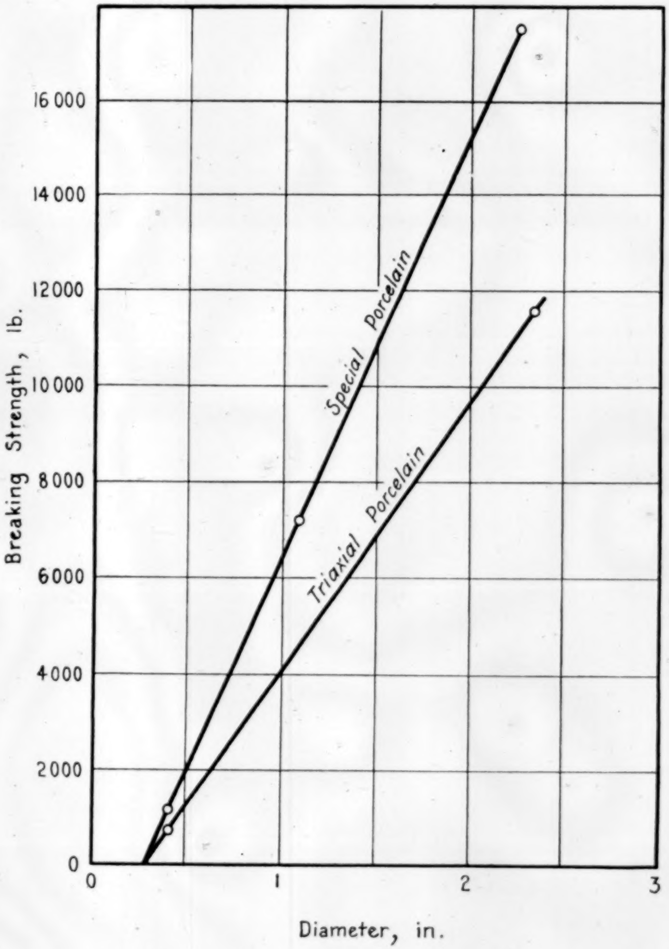

FIG. 4.—Relation between Breaking Strength and Diameter of Porcelain Test Specimen.

shaped pieces are found to be missing from between the rough surfaces. It appears as if failure occurs smoothly first at or immediately surrounding a flaw, and as the crack spreads the loading on the unbroken portion begins to increase very rapidly resulting in shattering. The smooth portion is very small with the smallest specimens, except when these have failed with very low loads indicating strains in the specimen. With the $1\frac{1}{8}$-in. specimens, the smooth area is usually about $\frac{3}{8}$ in. in diameter, and about $1\frac{1}{4}$ in. in diameter with the $2\frac{1}{4}$-in. specimens.

On the basis of these experiments, we may draw the conclusions that the relative strengths of different porcelains may be compared by means of small tensile specimens. On account of the greatly increased difficulty in forming, firing and loading porcelain pieces of large cross-section, their strength cannot be calculated on the basis of tensile specimens even as large as one square inch in area, as with these larger specimens the strength increases more nearly in proportion to the diameter than to the cross-section.

Table II.—Average Tensile Strength of Specimens of Different Sizes.
(Specimens formed by throwing.)

Size of Test Piece.		Breaking Strength, lb.	Tensile Strength, lb. per sq. in.	Ratio Special to Triaxial.
Diameter, in.	Area, sq. in.			
Triaxial Porcelain.				
0.408	0.131	763	5 824	
2.33	4.18	11 524	2 754	
Special Porcelain.				
0.409	0.133	1 042	9 508	1.63
1.125	1.0	7 149	7 149	
2.25	4.0	17 435	4 359	1.58

If the results obtained are plotted on the basis of tensile strength against cross-section, we obtain the curves given in Fig. 3. Plotting breaking strengths against diameters of test specimens gives substantially straight lines (Fig. 4) which may be expressed within the limits of experimental error by the equation:

$$S_1 = (d_1 - \tfrac{1}{4}) \frac{S_2}{d_2 - \frac{1}{4}},$$

where S_1 = strength of specimen; d_1 = diameter of specimen; S_2 = strength of small test specimen; and d_2 = diameter of small test specimen.

Further work is being done to determine how valuable this equation may be in connection with the design of heavy duty insulators or other objects.

TESTS FOR SOILS WITH RELATION TO THEIR USE IN THE SUBGRADE OF HIGHWAYS.

By A. T. Goldbeck and F. H. Jackson.

Owing to radical changes in the character of the traffic on our highways the problems of road design are today different in some respects from those of ten years ago. This condition has largely been brought about by reason of the extensive use of heavy motor trucks. With increasing wheel loads we have come to recognize the great importance of obtaining adequate support for our road surfaces so that they will not be unduly distorted under heavy loads. It is well known to road engineers that identical types and designs of roads are not equally successful in carrying like traffic in different parts of the country. Even though constructed with equal care some road surfaces fail utterly, while others carry equal traffic with little maintenance expense. The explanation of this difference must lie in the difference in support offered by the subgrade to the road surfaces. Practical road engineers know in a general way that certain types of soils when saturated with water have very little bearing value and that others have comparatively high bearing value. They also know in general that certain soils are impervious but that when once saturated are extremely hard to drain and further that other soils, owing to their porous structure, drain very readily.

It would serve a very useful purpose if the difference in these soil types which affect the stability of the road surface could be definitely and accurately recognized through the medium of laboratory tests, and it is the aim of this paper to briefly discuss some of the tests which are being investigated at the present time by the Bureau of Public Roads in an effort to finally determine which of them are most satisfactory.

The laboratory has worked out a series of tests designed to give some information regarding the following physical properties of subgrade materials: gradation, water-holding capacity, moisture equivalent, vertical capillarity, air shrinkage, slaking time, cementing value and the percentage of colloidal material as determined by adsorption. The relative bearing power of the soil under various conditions of density and moisture content is also being investigated.

Preparation of Soil Samples.

One of the most difficult problems in connection with the laboratory examination of soils is that of preparing materials so that they may be accurately sampled and studied. Many soils when received in the laboratory are so lumpy due to the clay content that it is exceedingly difficult to break them up without actually crushing some of the grains. It has been found, however, that most soils if handled carefully, may be prepared for testing substantially in accordance with the following scheme:

A $\frac{1}{5}$-cu. ft. sample of the soil as received from the field is broken up in a porcelain mortar, using a rubber-covered pestle, until the lumps of clay are small enough to pass through a $\frac{1}{4}$-in. screen. Great care must be exercised, especially with certain materials containing soft or friable sand, to prevent crushing of the grains. That portion of the sample which is retained on the $\frac{1}{4}$-in. screen is considered as gravel and is not used in connection with any study of the physical properties of the soil with the exception of its mechanical analysis and bearing power. The material passing the $\frac{1}{4}$-in. screen consisting of sand and clay is then passed through a soil pulverizer which consists essentially of two adjustable rubber rolls operated by an electric motor, between which the soil is fed. The rolls are adjusted to allow the soil to pass through them without clogging and yet with sufficient pressure to pulverize the clay fragments. By feeding the soil through very slowly it has been found possible to satisfactorily reduce most of the soils so far encountered. In especially obstinate cases it may be necessary to complete the preparation of the soil by rolling it out in a very fine layer on a rubber pad. It must be borne in mind, however, that the preparation of a clay soil for testing is an operation requiring great patience and care. The accuracy of the results of many of the tests depend largely on whether the sample has been reduced to its ultimate degree of fineness, at least in so far as it is possible to accomplish this end by mechanical means.

MECHANICAL ANALYSIS.

The method of mechanical analysis used is a modification of the method of soil analysis developed many years ago by the U. S. Bureau of Soils. Unlike the latter, however, there is no attempt made to separate the extremely fine grain sizes, a process which requires either prolonged sedimentation or centrifuging. The object of this test is simply to separate the fine silt and clay from the sand so that a sieve analysis of the latter may be made. The method also gives by difference the amount of combined clay and fine silt in the soil. The procedure is as follows: A 500-g. sample of the soil obtained by quartering the material prepared as previously described is passed through a 10-mesh sieve and the material retained thereon is recorded as coarse sand over 10-mesh. In case there is an appreciable quantity of gravel in the soil its percentage is computed from the weight of material retained on the $\frac{1}{4}$-in. screen as obtained during the preparation of the sample. A 50-g. sample of the soil which will pass a 10-mesh sieve is then obtained, great care being taken to sample accurately. The sample is placed in a glass jar about 15 cm. in height and 8 cm. (see Fig. 1) in diameter and provided with an aluminum screw top.

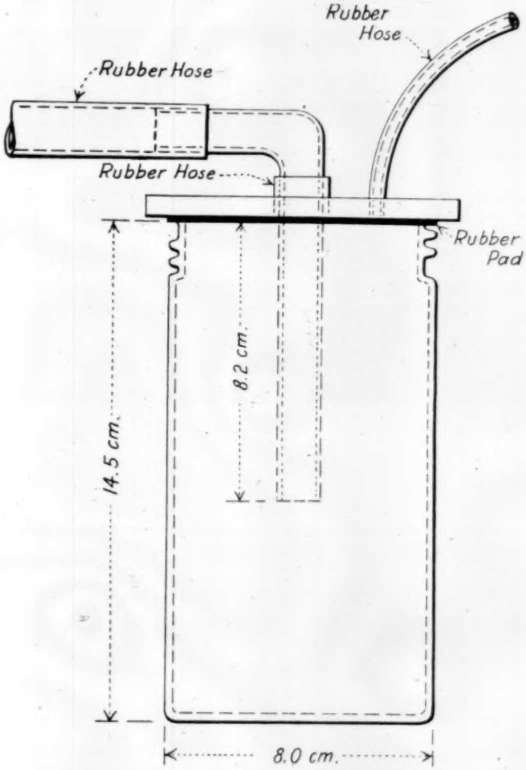

FIG. 1.—Siphon Tube.

Two hundred cubic centimeters of water and 5 cc. of dilute ammonia water are added and the jar is revolved in an agitator for one hour for the purpose of disintegrating any aggregations of soil particles which exist. The agitator consists of a wooden frame holding six jars so placed that they revolve about an axis perpendicular to the long axes of the jars. A view of the agitator is shown in Fig. 2. The contents are thus thrown from end to end of the jars twice during each

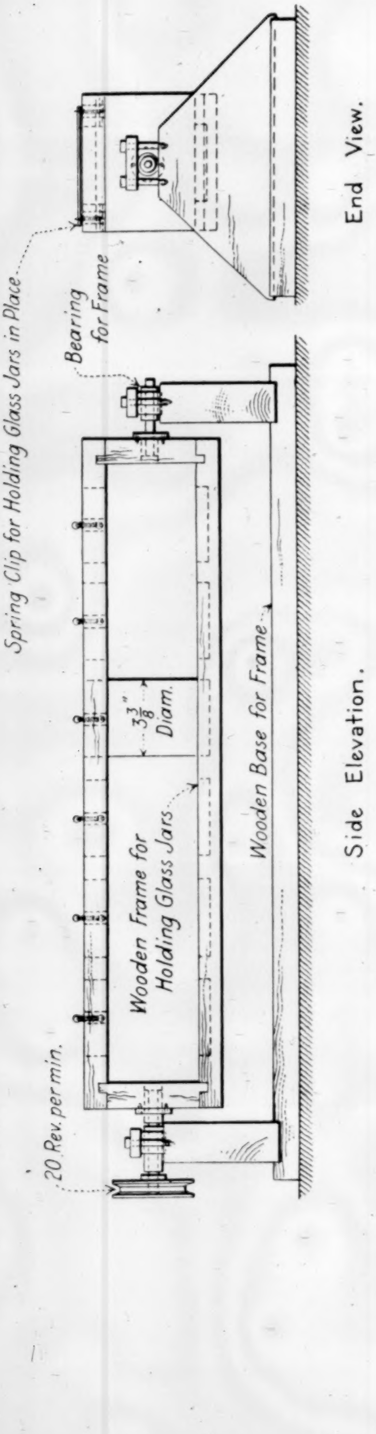
Spring Clip for Holding Glass Jars in Place
Bearing for Frame
End View.
20 Rev. per min.
Wooden Frame for Holding Glass Jars
3 3/8" Diam.
Wooden Base for Frame
Side Elevation.

FIG. 2.—Machine for Washing Soil Samples.

revolution, thus insuring maximum agitation. The jars revolve at the rate of 16 r. p. m. The function of the ammonia is to prevent floculation of the clay particles. The jar is then removed from the agitator and the contents allowed to settle for 8 minutes after which the water containing the material in suspension is siphoned off to a depth of approximately 8 cm. (see Fig. 1). The soil is again brought into suspension by means of a fine water jet under approximately 20 lb. pressure, and the above process repeated. The operation of washing, sedimentation and siphoning is continued until the wash water is approximately clear after 8 minutes sedimentation. A few drops of ammonia water are added after each washing. The soil in the jar is then dried at 100° C. and a sieve analysis made, using standard 20, 50, 100 and 200-mesh sieves. It will be noted that the above process divides the soil into four grain sizes which may be designated as "sand;" one (the material which will pass the 200-mesh sieve by analysis) which may be designated as "silt;" and one (the material removed by washing) which is a combination of fine silt and clay. The maximum grain size remaining in suspension after 8 minutes is approximately 0.030 mm. as determined by the method of the Bureau of Soils referred to above.

WATER HOLDING CAPACITY.

The water holding capacity of a soil may be considered as the maximum percentage of water which it is capable of retaining under any circumstances. The test for it is made in the laboratory in the following manner: A sample of the soil which has been prepared as described above is placed in a brass cylindrical box 1 cm. high and approximately 6 cm. in diameter. The bottom of the box is perforated with 150 holes each $\frac{1}{32}$ in. in diameter. The top of the soil is then struck off by means of a fine straight-edge and after weighing it is placed in a pan of water on a brass triangle and submerged just below the surface of the water for one hour (see Fig. 3). The surface water is then blotted off and the sample immediately weighed. The water holding capacity is determined on the basis of the dry soil.

MOISTURE EQUIVALENT.

The purpose of the so-called moisture equivalent determination is to obtain a measure of the power of the soil to retain moisture against the action of gravity. In other words it may be considered as an index of the difficulty which is likely to be encountered in draining the soil by ordinary methods. The term "moisture equivalent" has been defined by Briggs and McLane[1] as the percentage of moisture which is retained by a soil when it is subjected to a centrifugal force equal to 1000 times the force of gravity. In the preliminary work of the Bureau of Public Roads a centrifuge rotating at a speed of 2000 r. p. m. when filled has been used. The centrifugal force produced by this machine is approximately 750 times the force of gravity so that all the determinations for moisture equivalent which have been made are somewhat higher than the true moisture equivalents of the soil. For purposes of comparison, however, the results serve the useful

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[1] U. S. Bureau of Soils, *Bulletin No. 45.*

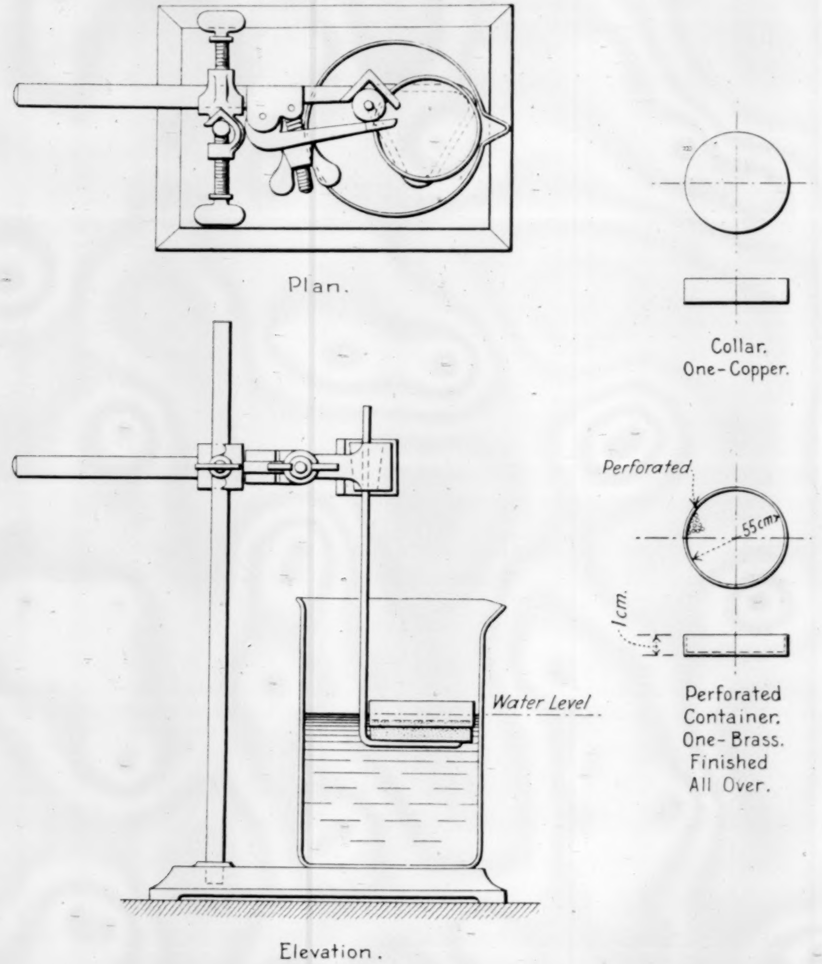

Plan.
Collar.
One-Copper.
Perforated
5.5cm
1cm.
Water Level
Perforated
Container.
One-Brass.
Finished
All Over.
Elevation.

FIG. 3.—Apparatus for Determining Water Capacity of Soils.

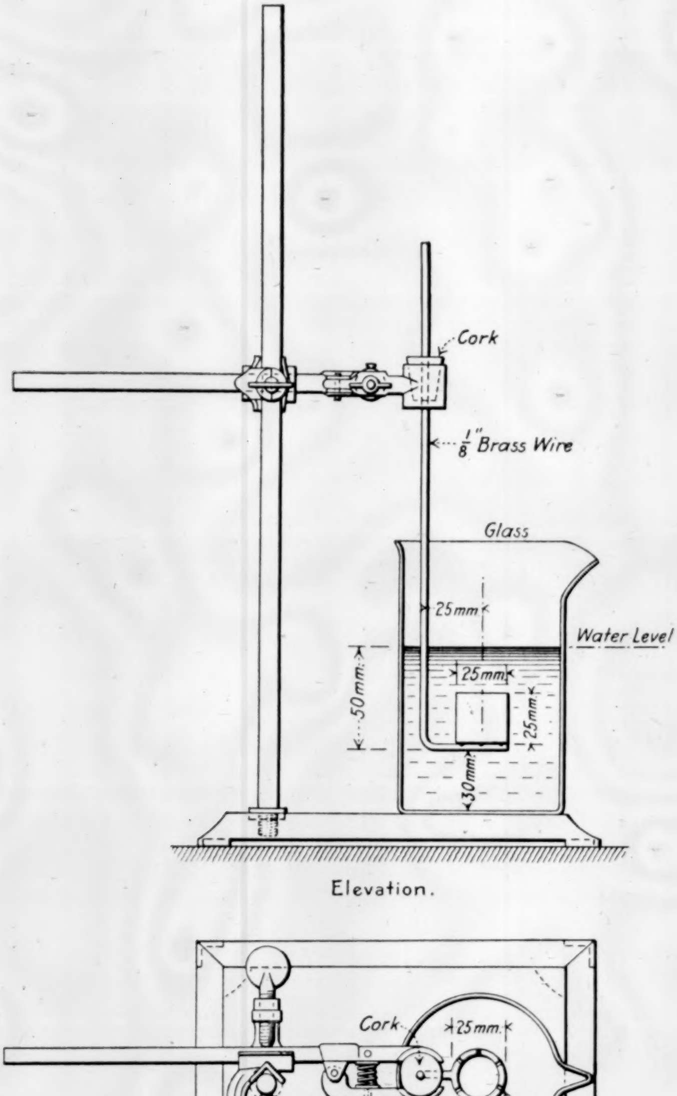
purpose of indicating the relative degree with which various soils will retain moisture. This determination is made on a 5-g. sample of the soil which has been prepared as previously described. The soil is placed in a Gooch crucible and allowed to take up water by vertical capillarity until saturated. After standing over night in a saturated atmosphere, the crucible is placed in a Babcock cup containing a small rubber stopper to serve as a cushion and provided with a hole sufficiently large to take the water thrown out during centrifuging. The cup is provided with a brass cap to prevent evaporation. An arbitrary limit of one hour has been fixed as the time of centrifuging. This time is not in every case sufficient to throw out the maximum amount of water at the speed used. It is considered to be sufficiently accurate, however, for the work in hand. Moisture equivalents are obtained by weighing the soil after centrifuging, drying to constant weight in an oven of 100° C. and again weighing. The moisture equivalent is the percentage of water, based on the dry weight of the soil, which is retained after centrifuging.

VERTICAL CAPILLARITY.

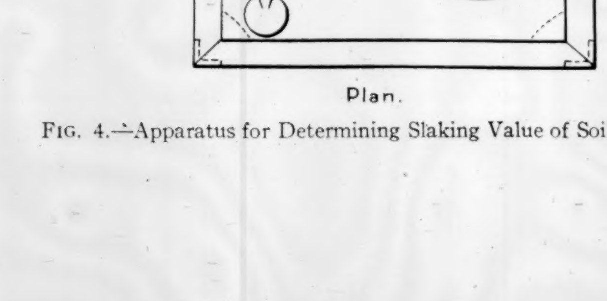
This determination is made for the purpose of ascertaining the average percentage of water which will be lifted a distance of 20 cm. in a column of dry soil 25 mm. in diameter. It is of value for comparative purposes only and does not necessarily bear any relation either to the total capillary lift of the soil or the maximum percentage of water which it is capable of holding by capillary attraction. A sample of the soil prepared as described is poured loosely into a 25-mm. glass tube and the tube is jarred until a height of 20 cm. has been reached and no further settlement takes place. A piece of cheese cloth is fastened to the lower end of the tube to hold the soil in place. The lower end of the tube is then just immersed in water. When capillary water reaches the top of the soil column the tube is weighed and the amount of water taken up by capillarity thus determined. This weight, expressed as the percentage of the dry weight of the soil, may be considered as the average percentage of moisture which will be taken up by capillarity under these conditions.

AIR SHRINKAGE.

The maximum contraction in volume which will take place in a given soil when dried in air at ordinary temperatures is of interest in connection with the study of the physical properties of soils. An approximate determination may be made in the following manner: A sample of soil passing the 10-mesh sieve is mixed with a quantity of water approximately equal to its moisture equivalent. The soil is


Cork
1/8" Brass Wire
Glass
25mm
Water Level
25mm
50mm
25mm
30mm

Elevation.


Cork
25mm.
Vents

Plan.

FIG. 4.—Apparatus for Determining Slaking Value of Soils.

then placed in a small flat cylindrical porcelain dish approximately 6 cm. in diameter and 1 cm. high, struck off level with a small trowel and weighed. The sample is then placed in a desiccator and weighed at frequent intervals until no further loss in weight is recorded. The percentage of the final volume in terms of the original volume is determined by filling the pan containing the dried soil sample with mercury. Knowing the volume of the pan and the volume of the mercury required to fill it after contraction of the soil has taken place the percentage of contraction may be calculated. The volume of mercury in the container is controlled by means of a glass plate which is pressed down firmly over the top of the pan, thus squeezing out the excess.

TIME OF SLAKING AND CEMENTING VALUE.

The time required to slake in water may be considered as an indication of the character of the clay content of the soil. The determination is made in the following manner: A mixture consisting of equal parts by weight of soil and powdered quartz, both passing a 200-mesh sieve, is mixed with 20 per cent of water and molded into 25 by 25-mm. briquettes under a pressure of 130 kg. per sq. cm. The briquettes are then dried in air for 20 hours and in an oven at 100° C. for 4 hours after which they are cooled 20 minutes in a desiccator and tested. For the slaking test, the briquette is placed in a brass ring submerged in water, as shown in Fig. 4, and the time required to slake through the ring is recorded as the slaking time. For the cementing value test, the briquettes are tested in the Page impact machine, in accordance with the method of the Bureau of Public Roads.[1]

ADSORPTION TEST.

This test has been developed to determine the adsorptive properties of soils for basic aniline dyes as a measure of the colloidal content and plasticity of subgrade road materials. About 20 g. of soil are taken from the sample used in the bearing power test and after passing a 200-mesh screen are brought to constant weight at 100° C. From this sample 0.2 g. are carefully weighed out on a sensitive chemical balance and transferred through a wide neck funnel to a 30-cc. globe-shaped separatory funnel (Fig. 5-A) containing about 2 cc. of the dye solution employed in the test. This solution consists of one part per thousand of commercial methyl violet in distilled water, and a convenient quantity should be made up in advance in order to maintain a constant strength during a large number of tests.

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[1] Department of Agriculture, *Bulletin No. 347.*

The weighed sample is then shaken up in the separatory until the dye solution is completely decolorized and the material settles down in a floculated condition, when it is run into a filtering tube closed at one end with filter paper (Fig. 5-B) and the funnel washed clean with the dye solution and drained into the tube. This tube should measure about 7 in. by $\frac{1}{2}$ in. inside diameter and be drawn at the lower end for a distance of one inch to a stem having a $\frac{1}{4}$-in. inside diameter and connected by a straight ground glass joint with a short stopper tube. This tube is required to insert the filter paper (disks $\frac{3}{8}$ in. in diameter) snugly in place in the narrow ground glass stem of the percolator as

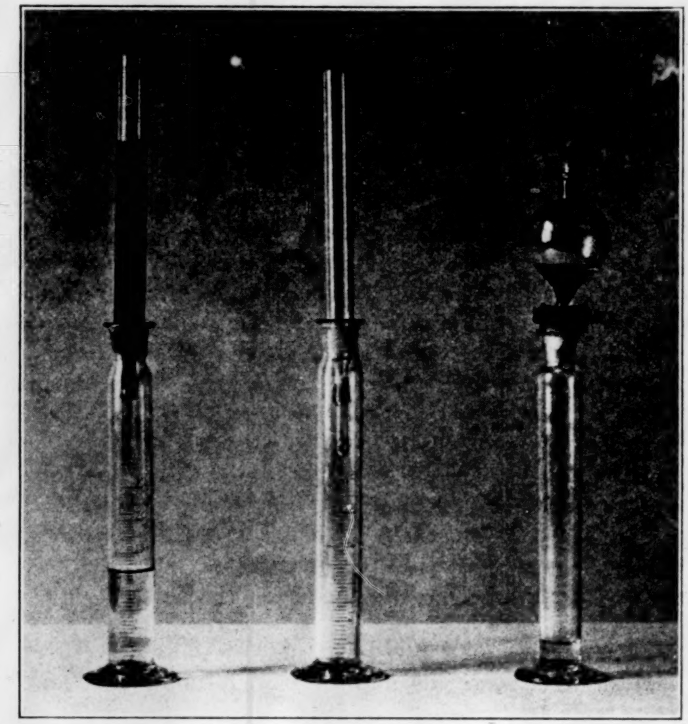

FIG. 5.—Tubes Used in Adsorption Test.

A. Separatory with wide neck funnel inserted containing coagulated clay and decolorized dye solution.

B. Filtering tube inserted in 25-cc. graduate showing stopper tube at bottom and ground glass joint with filter paper in place.

C. Filtering tube containing dye solution inserted in graduate after completion of test. Coloration in stopper tube does not show in figure.

well as to assure a uniform rate of flow of the dye solution through the material to be tested and should be filled with water before beginning the test.

The test consists in determining volumetrically the maximum quantity of dye stuff adsorbed by 0.2 g. of clay and is carried out by allowing the dye solution to percolate slowly through the clay into a 25-cc. graduate until a faint coloration appears in the liquid passing the filter paper, when the volume of the filtrate is read off (Fig. 5-C). This value multiplied by 5 would indicate the number of cubic centimeters of a 1 : 1000 dye solution adsorbed per unit weight of clay and may be termed the adsorption number. This number divided by 10 equals the percentage of dye adsorbed.

In the case of soils having exceptionally low adsorption it will be found desirable to increase the test sample to 0.5 g. The adsorption number is then obtained by multiplying the volume of decolorized solution by 2. In some few instances where exceptionally plastic clays were encountered, a graduate of 50-cc. capacity was required to collect the decolorized solution, and in one instance, 100 cc. passed a 0.2-g. sample before the end point of the reaction was reached.

COMPARATIVE BEARING POWER.

The test which has been developed for determing the comparative bearing power of soils is only of value in so far as it offers a basis of comparison between soils of dissimilar nature. As it is practically impossible to prepare a soil in the laboratory so as to duplicate field conditions, it has been necessary to make the test on samples prepared in an arbitrary way. It is believed, however, that results obtained by this method will assist materially in determining which of the physical properties of the soil are of the most significance in determining its value for use as a subgrade material. The method may be briefly described as follows:

The soil prepared as previously described is mixed by hand with just sufficient water to enable it to be thoroughly kneaded and placed in the mold homogeneously. It is then subjected to an initial pressure of 30 lb. per sq. in. preparatory to making the bearing power test. A tight-fitting plunger is used for this purpose and is removed after the proper compression has been obtained. The apparatus for making the bearing power test consists essentially of a brass cylinder (area 10 sq. in.) securely fastened to the moving head of a 20,000-lb. universal testing machine, a brass ring for confining the soil vertically and insuring perpendicular application of the load, and two 0.001-in. Ames dials, so mounted as to measure the penetration of the brass

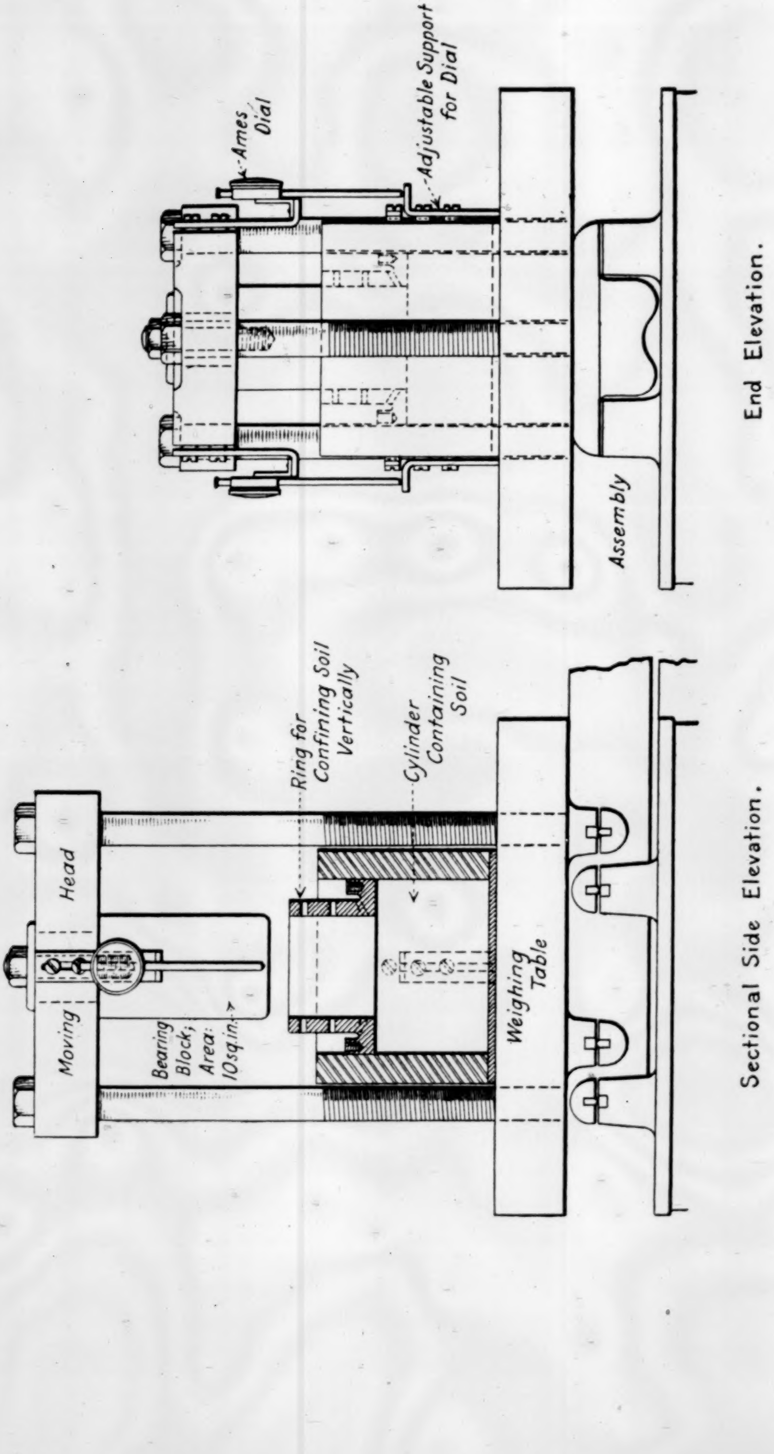
Ames Dial
Adjustable Support for Dial
Assembly
End Elevation.
Ring for Confining Soil Vertically
Cylinder Containing Soil
Moving Head
Bearing Block; Area: 10sq.in.
Weighing Table
Sectional Side Elevation.

FIG. 6—Apparatus for Determining Comparative Bearing Power of Soils.

cylinder with respect to the cylinder containing the soil. A drawing of the apparatus is shown in Fig. 6. Having subjected the soil to the initial pressure desired the confining ring is clamped in position so as to just touch the soil. The apparatus is then lined up and the head of the machine run down until the brass cylinder is approximately $\frac{1}{8}$ in. above the level of the soil. The two Ames dials are then adjusted to bear on the supports which are fastened to the cylinder containing the soil. The head of the machine is now run down at its slowest speed, care being taken to note the instant at which load is indicated by the weighing beam. Simultaneous readings of the dials and load are then taken at increments of 0.005 in. penetration up to 0.05 in. and at increments of 0.01 in. from 0.05 in. up to 0.2 in. This completes the bearing power test for the minimum moisture content and initial compression at 30 lb. per sq. in. The soil is then removed from the cylinder, thoroughly kneaded by hand, subjected to 50 lb. initial compression, and the bearing power test made in the above described manner. From the results obtained curves may be plotted showing the comparative bearing power of different soils for different conditions of moisture and initial compression applied. The weight of the soil and its volume before and after compression is also noted and

TABLE I.—TYPICAL RESULTS OF TESTS OF SUBGRADE SOILS.

Soil No.	Locality.	Moisture Equivalent.	Per cent Moisture by Capillarity.	Water Capacity.	Mechanical Analysis.						Cementing Value.	Time of Slaking.	Adsorption Number.	Bearing Power							
					Sand, per cent. Between				Silt, per cent.	Clay,[1] per cent.				Load in lb. at 0.1 in. Penetration.							
														(1)		(2)		(3)		(4)	
					10–20	20–50	50–100	100–200						Water, per cent.	Load.	Water, per cent.	Load.	Water, per cent.	Load.	Water, per cent.	Load.
158	Maryland....	2	10	22	27	51	16	3	1	2	..	..	..	0.2	600	2	500	10	250	22	0
29	California....	9	34	30	1	41	23	13	13	9	33	6	50	..	..	..	..	..	..	..	..
S. C.	Maryland....	10	16	..	19	45	7	3	6	19	14	4	..	4	625	8	500	10	275	..	..
80	Oregon......	17	26	41	4	9	9	14	34	30	64	17	45	15	548	17	466	26	34	28	20
56	Missouri.....	19	33	47	1	3	3	3	69	21	..	..	25	14	420	19	440	33	0	..	..
55	Missouri	19	27	47	3	8	4	4	55	26	82	8	..	16	635	19	780	26	135	47	0
140	Ohio........	20	33	44	5	11	5	6	47	26	11	180	..	13	495	20	285	33	0	..	..
9	Pennsylvania	20	29	..	..	1	1	1	58	39	9	4	10	11	445	20	440	29	25	..	..
51	Iowa........	22	28	50	5	15	11	12	29	28	134	10	..	18	590	22	245	28	45	50	0
59	Illinois......	23	30	55	..	3	5	3	63	26	358	11	80	16	440	23	407	30	35	36	35
50	Iowa........	23	36	55	1	8	7	6	44	34	93	8	45	20	565	23	480	36	70	53	0
33	Minnesota...	25	33	76	1	2	2	1	59	35	64	4	180	20	415	25	230	33	30	69	0
62	Illinois......	25	30	53	5	17	8	6	24	40	132	14	55	22	530	25	440	30	225	52	0
63	Illinois......	25	25	63	1	4	4	2	58	31	144	7	55	20	580	25	530	29	205	41	20
61	Illinois......	26	32	56	1	11	7	5	18	58	46	31	75	22	500	26	515	32	200	43	20
70	Oregon......	26	29	54	1	6	4	2	44	43	29	5	45	21	565	26	148	29	83	35	11
78	Oregon......	26	31	50	2	15	17	21	28	18	51	6	45	20	525	27	465	31	329	43	30
89	California....	29	42	..	..	..	..	..	..	..	470	13	..	18	713	22	686	29	205	39	68
67	Oregon......	32	36	75	2	6	6	11	42	33	174	7	130	23	470	28	440	33	212	41	50
82	Oregon......	33	33	55	..	2	2	4	55	37	63	6	60	24	540	32	110	39	45	41	15
91	California....	34	44	71	2	2	4	15	38	38	370	10	10	25	410	34	175	44	45	71	0
73	Oregon......	41	43	75	..	4	8	10	21	57	273	20	140	37	525	40	540	43	300	64	10

[1] The term "clay" as used in this table refers to the fraction removed by 8 min. sedimentation. It is in reality a mixture of very fine silt and clay.

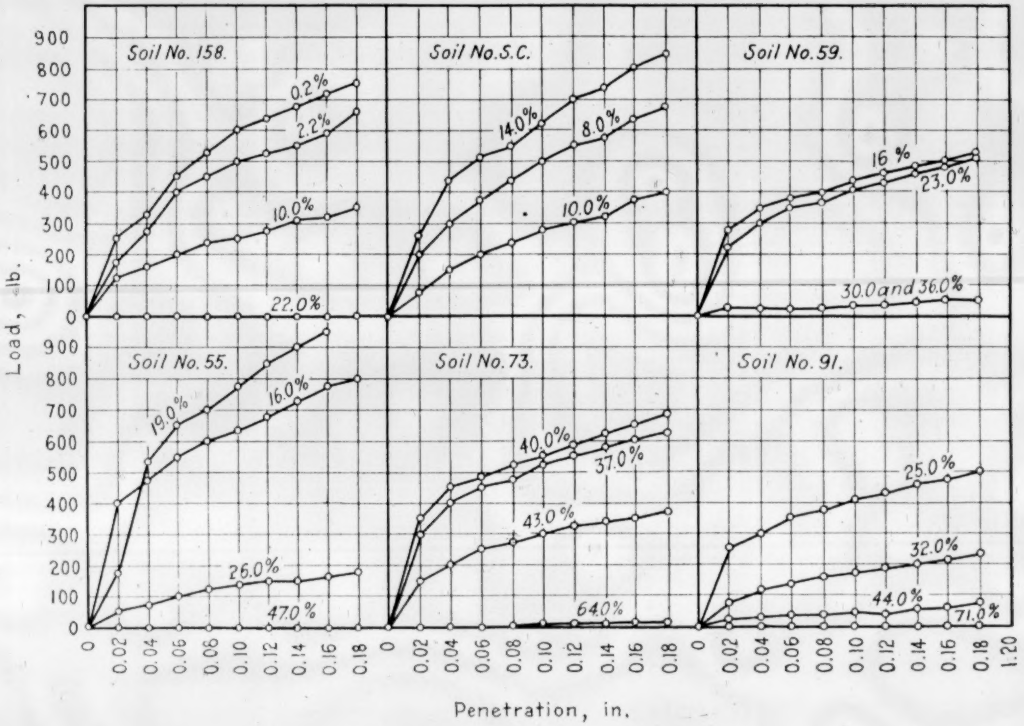

FIG. 7.—Relative Bearing Power of Soils. Percentages of Water Used in Each Case as Indicated.

from this information and the specific gravity of the soil, values for density under different conditions of moisture and initial compression are computed.

DISCUSSION OF RESULTS OBTAINED.

Practically all of the time which it has been possible for the laboratory to devote to this subject has so far been taken up in studying suitable methods of testing. This applies particularly to the problem of designing a satisfactory laboratory test for bearing power. Then, too, the problem of properly preparing samples for test has given some trouble. It has not been possible, therefore, to take up as yet a systematic study of actual subgrade soils, although the tests outlined above have been made on quite a number of such materials. No attempt will be made, therefore, at this time to go into a detailed discussion of results, the purpose of the paper being rather to describe methods of testing. For the purpose of showing the general range in values which have been obtained, a series of results for typical soils from various parts of the country are shown in Table I. In this table the relative bearing power of the soils is given as the load in pounds required to produce a penetration of 0.1 in. under the conditions of the test and with an initial compression of 50 lb. per sq. in. Values for bearing value are given for four moisture conditions: (1) the minimum amount of water which can be worked into the soil, (2) the moisture equivalent, (3) the moisture determined by vertical capillarity and (4) the maximum amount of water which can be worked into the soil.

The determination which apparently yields the greatest amount of information is the test for moisture equivalent. As has been noted, this test is supposed to be an indication of the moisture retentiveness of a soil. Results of tests so far would indicate that, in general, moisture equivalents increase with the percentage of very fine silt and clay in the soil. It has been possible, in fact, to work out an empirical formula which indicates a fairly definite relation between the moisture equivalent and mechanical analysis. There are sufficient exceptions, however, to indicate that certain other factors, possibly percentage of loam, etc., influence this relation.

Results of the tests would indicate also that the bearing power of most soils is not appreciably reduced by the addition of moisture up to the moisture equivalent. This apparently applies moreover to all types of soils from pure sand to heavy clays. When the soils become saturated beyond the moisture equivalent, however, a rapid reduction in bearing power apparently takes place, usually disappearing completely at or before the water holding capacity of the soil has been reached. These general comments are given here simply to indicate possible existing relations and are in no sense definite conclusions, which manifestly can not be drawn without much additional study.

For purposes of illustration there have been plotted in Fig. 7 the results of a number of typical bearing power tests. These tests indicate in a general way the range in values obtained, as well as the influence of moisture on the bearing power.

In conclusion, the authors would emphasize the fact that the study of subgrade soils is a very important subject upon the successful conclusion of which is involved economy in road construction. It seems apparent that much time and thought will be required before definite conclusions can be drawn. The authors present the above outline of test methods in the hope that others may be induced to take up the subject, devoting to it the time and attention warranted by its importance.

MEASUREMENT OF IMPACT.

By Earl B. Smith.

The measurement of the actual force of impact is accompanied by a great many difficulties and requires special apparatus used with a high degree of skill. It is also rather difficult to know when the actual maximum value of the force has been obtained. Several methods have been used in attempts to determine the force of an impact blow and it is the purpose in this paper to describe two of these methods, namely, the autographic and the deformation methods.

Our usual conception of the force of a blow is in terms of work or energy, but to make actual use of the force of impact in comparing effects, and in the designs of structures and machine parts, we must know the actual intensity of the blow in pounds and not in foot-pounds. The fundamental formula for the energy in a moving mass, $K = MV^2/2$, does not show the actual force in pounds with which this mass may strike another mass. We may know the actual force of the blow only when we determine the time and distance in which the mass is brought to rest. In other words, we must know the rate at which the velocity of the mass is changed. This rate of velocity change from some value to a lesser or to a zero value is known as "deceleration." The numerical value of deceleration may be known from the relation

$$a = \frac{V_1 - V_2}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

That is, deceleration is equal to the difference between an initial velocity, V_1, and the final velocity, V_2, divided by the time, t, to make this velocity change. V_2 is equal to zero in most cases with which we are concerned.

The actual force of impact in pounds is given by the formula

$$F = Ma = \frac{W}{g}a \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

In the use of this formula the value of the acceleration of gravity is known, that is, $g = 32.2$; the weight of the mass, W, in pounds may be readily obtained; but the value of the deceleration, a, is very difficult to determine. Its determination requires very accurate measurements of small increments of time and distance. This formula is, however, the basic relation between impact and force, and it is only by this relation that we may hope to secure accurate results.

When one mass strikes another the force of the blow depends upon the deceleration value. If the velocity of the moving mass is changed to zero in a very short time the resulting force is larger than when the velocity change is over a longer period of time. The time of velocity change is in turn dependent upon the distance through which the change takes place.

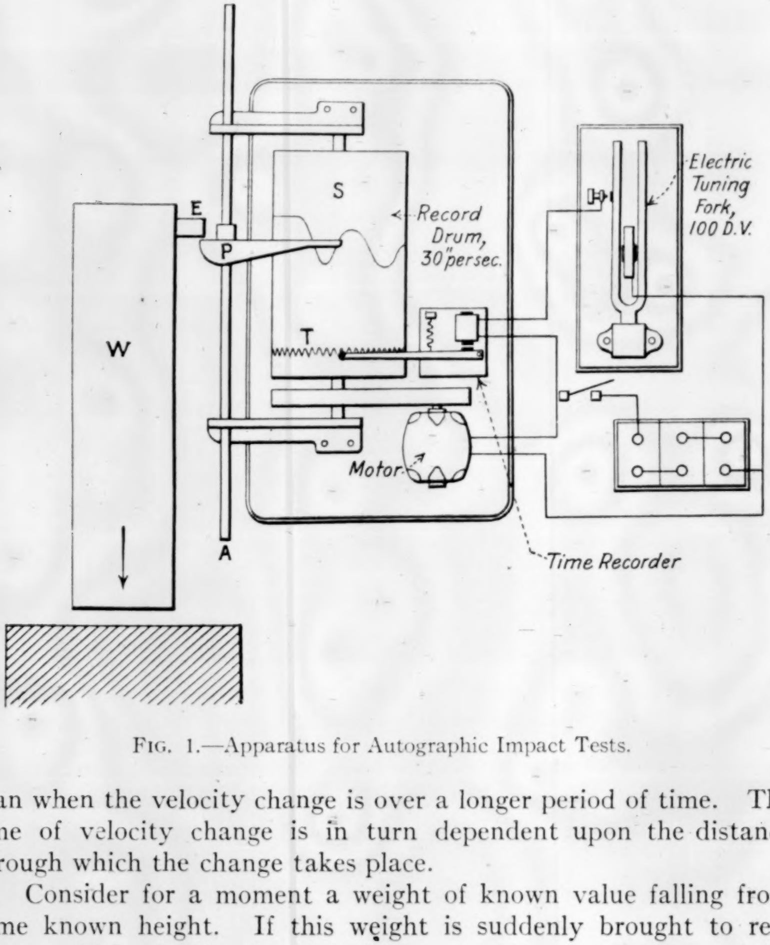

FIG. 1.—Apparatus for Autographic Impact Tests.

Consider for a moment a weight of known value falling from some known height. If this weight is suddenly brought to rest when striking a hard and practically immovable mass, the force of the blow in pounds will be very high, its exact value depending upon the deformation of the materials of the two bodies. But if this same weight falling from the same height should strike another body which is not so hard and may possibly move slightly under the impact, the resulting force of impact in pounds will be much less. Again, under the same conditions of weight and height of fall, if the weight should strike a spring or a block of rubber the deceleration value is further decreased from the value in the other cases with the result that the impact force in pounds is comparatively small. In all these cases the amount of energy possessed by the moving body in foot-pounds at the instant of contact is the same. From this it may be readily seen that the amount of energy possessed by a moving body is in no way an indication of the force of impact in pounds, but that the force is dependent upon the resistance and the deceleration value.

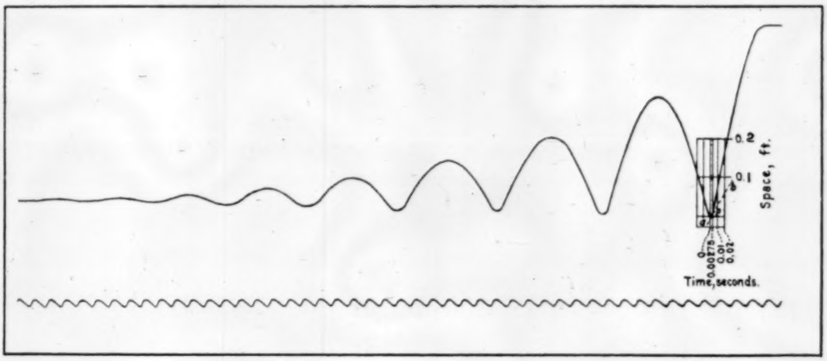

FIG. 2.—Space-Time Curve of Vertical Movement of a Truck Wheel.

AUTOGRAPHIC METHOD.

The only way in which the value of the force of impact, in pounds, may be determined accurately is by the use of a "space-time" curve autographically drawn at the instant of impact. That is, the movement and position of the mass (or weight) must be graphically indicated with respect to each time increment. The apparatus which has been used by the U. S. Bureau of Public Roads to obtain the autographic space-time curve is shown diagrammatically in Fig. 1. The recording drum carries a sheet of paper and revolves at such a speed as to give the paper a circumferential velocity of about 30 in. per second. The magnetic time recorder is in series with the operating magnet of the tuning fork, and makes an oscillating time record line, *T*, on the paper, indicating 0.01 second for each 0.3 in. of paper record. By interpolation it is easy to get time intervals of less than 0.001 second.

The falling weight, W, carries an extension, E, which engages with the pencil arm, P, and causes the pencil to trace the exact movement of the weight just before and during contact. For weights falling more than a few inches this scheme has been found satisfactory, since it is the maximum deceleration value which is desired. This maximum value occurs, of course, during contact, and in the case of soft or yielding materials it occurs just before but near the final point. It is sometimes possible and more convenient to connect the guide rod, A, directly to the weight and thus obtain a record of the entire movement. This is done in the case of determining the impact of a truck wheel on the road. In the use of such an instrument precaution must be taken to prevent any lost motion in the apparatus, and to prevent any natural periods of vibration in the pencil arms and connections. An ink pen is not suitable for tracing the records. It is absolutely essential that the line be traced by a sharp hard pencil lead on ledger paper, or by a bronze point on silicated paper.

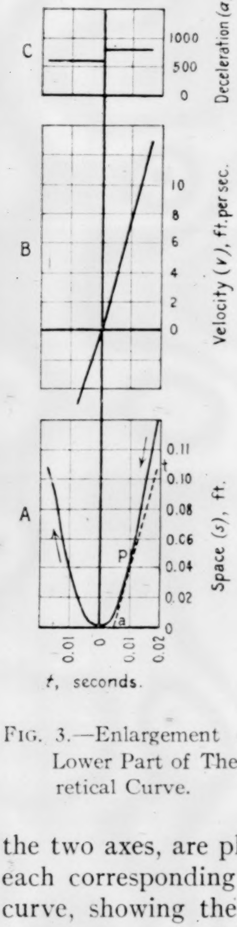

FIG. 3.—Enlargement of Lower Part of Theoretical Curve.

The curve in Fig. 2 is a reproduction of the space-time curve of the vertical movement of a truck wheel autographically drawn by this apparatus. The vertical ordinates are the actual distances passed over by the wheel; and the horizontal distances represent time intervals. An enlargement of the lower part of a theoretical curve is plotted in Fig. 3, for the purpose of showing the method of obtaining the final deceleration value. To the "space-time" curve, A (Fig. 3), are drawn several tangents, as ta. The values of these tangents, to the scale of the two axes, are plotted in curve B to the same time axis and above each corresponding tangent point. This gives a "velocity-time" curve, showing the velocity at any time. Likewise, tangents to this latter curve are plotted in curve C; this gives the "deceleration-time" curve, showing the deceleration at any time. In this particular case the space-time curve (downward portion) was a parabola whose equation is

$$t^2 = 0.0025\, S \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and since values of the tangents to a true parabola are directly proportional to the abscissas, the velocity curve *B* is a straight line; also since this is a straight line its tangent is a constant, giving the horizontal lines at *C*. The upward portion of this curve has a slightly different equation.

This graphical solution is based on the fact that any point on the space-time curve represents the distance passed over at that time; or the velocity, that is, the first derivative,

$$dV = \frac{ds}{dt} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

is the tangent to the curve. Also, that the first derivative of the velocity curve, or the second derivative of the space-time curve, is the deceleration.

Taking the values of the coordinates at the point *P*, and from the equation of the curve,

$$da = \frac{d^2s}{dt^2} = \frac{d^2t^2}{0.0025\ dt^2} = 800 \quad \ldots\ldots\ldots\ldots \quad (5)$$

which corresponds to the graphical value.

Referring again to Fig. 2, tangents drawn to the space-time curve, as *ab*, show a maximum value for the deceleration of 1400 ft. per second per second. Then from the fundamental equation, $F = Ma$, when W is 2000 lb. the resulting impact force is

$$F = \frac{2000 \times 1400}{32.2} = 87{,}000 \text{ lb} \quad \ldots\ldots\ldots\ldots \quad (6)$$

This autographic method may be found convenient for use where weights are large and movements are comparatively slow, and where the deceleration values are probably not over 5000 ft. per second per second. It should be satisfactory for use in determining the impact of truck wheels, pile drivers, forging hammers, or any large mass striking a yielding substance or support. This method would be somewhat difficult to use where the velocity of the mass is high, and the mass strikes a hard and only slightly yielding substance or support.

DEFORMATION METHOD.

No very simple method for determining impact values that will give absolutely definite results has as yet been devised. A method for obtaining approximate comparisons of impact forces in pounds is based upon the fact that both impact and static forces may be made to produce deformations. This method consists simply in receiving the impact on a small copper cylinder, and to compare the deformation thus produced in the copper with the static force which will produce the same deformation on a similar cylinder. Since equal deformations will not be produced in the same material under both impact and static forces, the indications from the copper-cylinder method should be corrected by the use of some coefficient. This coefficient is not a constant and depends for its value upon several factors which are as difficult of determination as the impact value itself. This method does, however, give some approximate comparisons between impacts which may be of value in studying such forces when the variation in weight and height of fall is not very great.

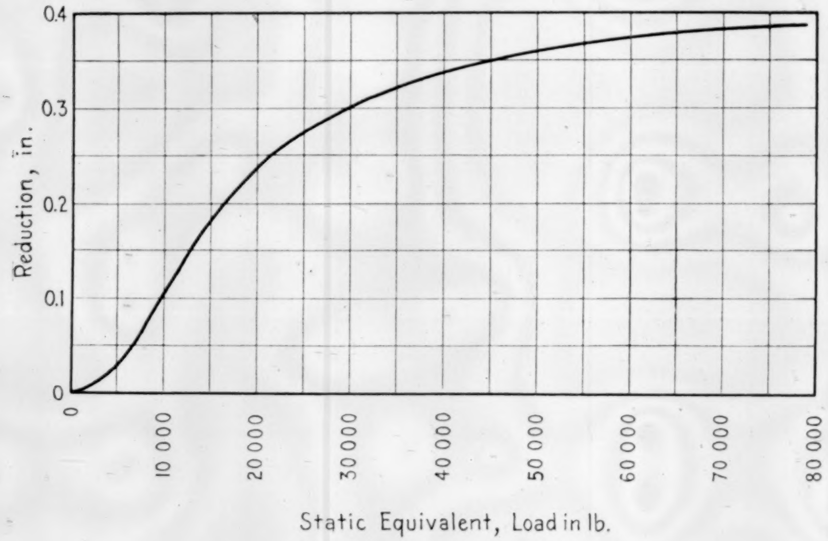

FIG. 4.—Calibration Curve Showing "Equivalent Static Force" Used in Copper-Cylinder Method.

A serious disadvantage in the use of this copper-cylinder method is that it introduces another factor in the result: the cylinder itself acts as a cushion, giving more deformation or deflection to the system and thus reducing the deceleration. When definite impact values are desired they are required under the actual conditions without cushioning effect, and it should be remembered that the measurement of this force by the copper-cylinder method gives results that may be considerably less than actual values.

Where only comparisons are desired, and not the actual values, this copper-cylinder method may be found convenient and reliable.

The cylinders are made from a pure copper rod $\frac{1}{2}$ in. in diameter, cut and accurately machined to 0.500 in. in length, allowing a variation of not more than 0.001 in. It has been found that the diameter of rolled copper rods is sufficiently constant and accurate to require no further machining. These cylinders are heat-treated in a gas or electric furnace in a bath of molten sodium and potassium nitrate crystals, in the proportion of 4 to 1, respectively. After the crystals are melted, requiring about 1200° F., the copper cylinders are carefully dropped into the bath and allowed to remain there for 30 minutes. The bath contents are then removed and allowed to cool to atmospheric temperature, after which the cylinders are removed by dissolving the nitrate crystals in warm water. A few of these cylinders are tested in a testing machine, under static loads, and an average curve of "load *vs.* deformation" is plotted, as shown in Fig. 4. For use in measuring impact one copper cylinder is placed under the plunger in a neat but loose fitting cylinder (Fig. 5), and the impact is received on the head of the plunger. The resulting deformation in the copper cylinder is measured with a micrometer and the "equivalent static force" is read from the curve (Fig. 4).

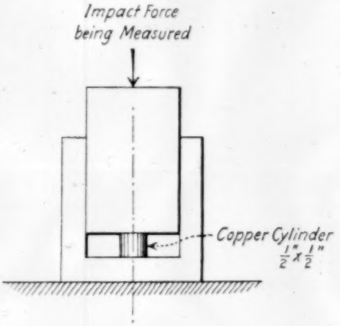
Impact Force being Measured
Copper Cylinder $\frac{1}{2}" \times \frac{1}{2}"$

FIG. 5.—Copper Cylinder in Position for Impact Test.

Of the two methods described the autographic method is the more accurate and reliable; the results are probably not more than 2 per cent in error. It does, however, require a recording apparatus and a timing device which are not readily secured from any of the manufacturers of physical apparatus. The apparatus used by the author in the laboratories of the U. S. Bureau of Public Roads was made especially for the purpose by the Bureau instrument maker for use in connection with an investigation to determine the impact of trucks on roads.

The copper-cylinder method has been used to a rather large extent in the determination of the impact of trucks. It does not give actual results; the results by this method should be considered only as comparisons, but the comparisons are reliable and useful when dealing with weights and distance which do not have a larger variation than about 5 to 1, and when the estimated deceleration is probably not over 3000 ft. per second per second.

DISCUSSION.

Mr. Margerum.

Mr. C. E. Margerum (*by letter*).—The remarks in Mr. Smith's paper calling attention to the distinction between energy of a moving body and the force which its collision with another body may produce, are timely and important. There seems to be a tendency in some quarters to confuse these two conceptions or to assume that one is proportional to the other. Special attention is called to the first sentence of the second paragraph of the paper where the fact is stated that test data must be expressed in pounds and not in foot pounds if the results are to be used in the design of structures.

The mathematical portion of the paper is interesting as it brings out the relations between work and force, but as a statement of a method of making accurate determinations of pressures produced by impact it does not seem to merit the commendation which is so liberally given to it in this paper. Mr. Smith underestimates the situation when he says that the value of the deceleration is difficult to determine, and that "its determination requires very accurate measurements of small increments of time and distance." How fine these measurements need to be and how seriously they will be affected by small errors in drawing the tangents and determining the exact point of tangency, or by small irregularities in the curve due to lost motion, vibration of the drum or its supports, eccentricity of the blow, or other factors, will be appreciated when one considers that the method depends on determination of the exact form of the extreme peak of a curve of which the total height is very slight.

In the case of impact of a truck wheel on the road, deceleration begins when the wheel in its downward motion passes through the level at which it would rest if it were standing still on the road. The deceleration portion of the space-time curve of the wheel's motion is the part between this point and the lowest point reached. Its height is a measure of the compression of the tire and wheel plus any displacement of the road surface which may occur while the downward motion is being arrested. The vertical force opposing the motion of the wheel varies from zero at the neutral point, or beginning of deceleration, to a maximum at or near the point of lowest depression of the wheel. The space-time curve method is an attempt to determine the maximum of this force by determining the deceleration at its point of greatest magnitude. The *average* pressure, in pounds, produced by impact of a moving body obviously is the energy of the body,

Mr. Margerum. expressed in foot-pounds, divided by the distance, in feet, in which the motion is arrested; as the product of force by distance must be the same in each case as the amount of energy is the same. If uniformly increasing resistance (pressure) could be assumed, the maximum pressure would then be twice the average. The space-time method, to be of value, must be sensitive and accurate enough to determine the amount by which the actual pressures depart from the condition of uniform increase proportional to distance.

In the curve shown in Fig. 2 the scale marked "Space, ft." indicates that the total deceleration portion of the curve is 0.0375 ft. or 0.45 in. high. As the pencil line will be at least 0.005 in. wide, and not smooth on the edges, enlargement of the diagram by photography will help, but will hardly do more than to enable a rough estimate of the deceleration to be made.

Enlargement of the diagram by increasing the movement of the tracing point by a lever or other device would increase the error due to the inertia of the tracing point and its supports and guides to an extent which would grossly distort the curve. At best these parts are subject to the same deceleration as the moving body.

Substituting 1 lb. for 2000 lb. used by Mr. Smith in his Eq. 6, we obtain

$$F = \frac{1 \text{ lb.} \times 1400}{32.2} = 43\tfrac{1}{2} \text{ lb.}$$

Accordingly the impact exerts a force tending to deflect the tracing point downward, equal to a pressure $43\frac{1}{2}$ times as great as the pencil arm and all parts attached to it; as these parts are subjected to the same deceleration as the wheel.

If one has determined the motion of the hub during impact why should one attempt the calculation of the time-space curve when the compression of the wheel and tire indicates the pressure directly? All that is necessary is to find the amount of the (elastic) deflection between hub and pavement under known increments of static load and to compare this with the deflection between these points on impact. This will give a practical measurement of the actual wheel pressure due to impact of trucks on roads, a determination which, as will be shown presently, cannot be made by Mr. Smith's method even if that method were capable of giving the deceleration value with absolute exactness.

One of the requirements fundamental to the application of the time-space curve method for the measurement of the force produced by impact is that the curve should represent the motion of a rigid mass which strikes a yielding object. To illustrate this point, consider that the weight W in Fig. 1 of the paper is of rubber, and that the hatched

Mr. Margerum.

object below is a steel anvil. The projection *E* obviously will not represent the motion of *W* as a whole after impact, as the motion of the lower end of *W* is stopped at the very beginning of the curve. Neither would *E* represent the true motion if it were placed at the center of *W* as the rubber above it would be moving more rapidly than that below. In the case of a motor truck this condition is even more pronounced.

While an accurate determination of the deceleration value of a point at the hub, if attainable, would give, except in the case of a cushioned wheel, a practically correct figure for the force of impact due to the wheel itself, it would be no indication of the pressure transmitted to the road through the wheel by the other parts of the truck. In fact the pressure due to the parts supported by the springs is normally less, at the time of greatest pressure from the impact of the wheel, than the actual weight of the spring-supported parts. On the other hand the axle, differential, and other parts which have a more limited deflection relative to the wheel will add to the pressure produced by the wheel's impact, but the time-space curve of the wheel will not answer for the calculation of pressures resulting from weights which move through different distances and at different times.

It does not appear from the paper whether the time-space curve method has been actually used in practical work, but the comparisons with the deformation method and the use of 2000 lb. as the weight on the wheel, convey the impression that the method is proposed to determine the pressure produced by the truck as a whole, for which purpose it is clearly unsuited.

My own interest in this paper comes principally from the broad statements made in criticism of the deformation method of measuring impact pressures. This method is used in determining the gas pressures due to explosions and the results are reliable and accurate. No coefficient or other correction is used, at least in American and French naval ordnance practice, because convincing investigations have shown no appreciable error to be corrected. Errors may easily occur in determining road shocks by the use of apparatus designed for gas pressure measurements; but with a device adapted to the test which is to be made, one may be assured that the error arising from the deformation method itself as distinguished from imperfections of application will be so small a percentage that such able investigators as Sarvau and Vieille and Charpy reported it as negligible.

It is believed that Mr. Smith should present very strong evidence before it will be logical to substitute his ideas as to the deformation method, for the conclusions which have stood for ma[illegible]s and have been formulated and confirmed by investigators of th[illegible] standing.

Mr. Smith. MR. E. B. SMITH (*Author's closure by letter*).—In reply to the statements made by Mr. Margerum in discussing my paper, I will say I believe we have fully realized the difficulties attending the full accomplishment of the space-time method of determining impact values. The points of tangency to the space-time curves and the time and space values are made by the aid of a microscope and a micrometer arrangement. In this way, we have been able to determine these necessary values very accurately. I believe it is possible by this method to secure very accurate results; however, when this method is used and only moderate accuracy and care is taken in measuring these curves, we finally get impact values which are sufficiently accurate for all practical purposes. It is not to be expected where this method of determining impact values may be employed for ordinary practical purposes that a very high degree of accuracy would be used. By the method as here presented it may serve as a reliable means of determining impact values and the final accuracy of the results will, of course, depend entirely upon the degree of refinement and care used.

Many analytical methods for determining impact values have been proposed and have not been found very satisfactory, as they depend upon several assumptions. The method proposed by Mr. Margerum—that of determining the increments of deflection between the hub and the pavement under static loads (in case of the truck wheel) and comparing this deflection with that of these same points under impact—depends upon several factors: (1) that these increments of deflection under impact may be conveniently and accurately measured; (2) that the resistance offered by the rubber tire through these various increments is exactly proportional or according to a straight line law—this we know is not the case—and therefore the deceleration value is not constant but is rapidly increasing; and (3) the assumption is made that the action of the resisting material (rubber in this case) is the same under static forces as it is under impact forces. On this last point, there is evidence that there is some difference in the action of materials under these two kinds of forces.

The value of an impact force expressed as the average pressure in pounds obtained by use of the energy equation does not get us anywhere, because the average force obtained in this manner may be far from the maximum force delivered, and it is the maximum force which is required and which should be used in all design work in connection with strength of materials. As I have stated before, the amount of energy possessed by a moving body is in no way an indication of the force of impact which may be delivered and measured in pounds, but this impact force is entirely dependent upon the resistances met with and the deceleration value. **Mr. Smith.**

The instrument shown in Fig. 1 is only a diagrammatic presentation of the principles and essentials necessary in a practical working apparatus. The instrument which has been used for drawing the space-time curves has given some very satisfactory and accurate results. The pencil motion, of course, has the same deceleration or acceleration value that the mass which is being measured may have, but it is so constructed that it operates in a straight line and has practically no rotary, angular or other distorting component in its motion. As was stated in the paper, such an instrument must be used with a great deal of care and skill; but this requirement is easily possible and not at all prohibitive. Of course, a loose-jointed instrument poorly constructed and operated by a novice would give worthless results.

The use of such an instrument for measuring impact forces is evidently improper when the moving mass producing the impact is of a spongy, elastic, or plastic material. It can be used only with rigid masses when precise results are required, but its use may be extended for practical purposes to masses which are not absolutely rigid.

The author does not claim originality for this method, it having been proposed at different times by physicists and mathematicians, but it is presented here in this form as a practical method for determining impact values the accuracy of which will depend entirely upon the pains and care taken in the construction and use of the necessary apparatus.

THE REFINING OF PETROLEUM.[1]

By C. K. Francis.

The process of refining petroleum often begins at the well, because crude oil is usually contaminated with water and may carry in suspension fine particles of sand which should be separated before being transported for further treatment. The processes for treating the oils on the producing property are of course very simple. The oil is permitted to stand long enough for the water and sand to separate, since oil may not be delivered to the pipe line when it contains more than two per cent of sand and water, commonly designated, bottom settlings or "B. S."

Some crude oils, especially those produced with gas, and water, come to the top of the well in an emulsified, or "cut" condition. This is due to the combination of mineral salts with a very small part of the oil, which, under the atomizing action of the pressure and gas, is so emulsified that ordinary washings or settlings effect no improvement. Oils of this class require special treatment which briefly consists of pumping the oil into a tank fitted with steam coils in which the oil flows upward through a body of warm water, then out through an overflow pipe to a storage tank to be delivered to the pipe line. An electrolytic process is used to some extent and sometimes soap powders are employed. Recently some success in purifying cut oil has been attained by the use of centrifugal machines. This method appears to be adaptable in the field when comparatively small quantities of oil are to be treated.

The true refining operations are conducted in works equipped with special apparatus which may be comparatively simple or very complex according to the completeness of the separation and number of products made. Pipe lines transport the bulk of the crude oil from the wells to the refinery.

The most important operation conducted in a refinery is that of fractional distillation. The distillation of petroleum is founded on a very simple process, a well-known example of which is that observed in the boiling of a tea kettle, with the difference, however, that when the vapor or steam is passed through a pipe and cooled it will collect or condense as water, the original substance, whereas, the hot vapors of petroleum, which separate when cooled according to their volatility, form different substances known as gasoline, kerosene, lubricating oils, etc.

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[1] All statements and specifications mentioned are presented with reference to Mid-continent Petroleum.

The first operation at the refinery is to place the crude oil in a horizontal cylindrical still which may range in capacity from 150 to more than 1000 barrels.[1] The oil is heated, the hot vapors from the still passing by means of an overhead pipe, known as the vapor line, into the condenser box, which usually consists of a series of pipes covered with water. The vapors are by this device cooled and condensed to the liquid form. The liquid passes from the condenser box to the receiving house, often called the "tail house," where it is inspected and directed to a tank known as a "run-down" tank. The stream of liquid flowing into the receiving house passes through a large trap provided with glass sides, the purpose of which is to permit the operator to observe the color or general condition of the stream, so it is appropriately designated a "sight box" or "look box." From the lower part of this box, portions of the liquid are withdrawn from time to time for inspection.

The first or light vapors given off from the crude oil furnish crude gasoline, and then increasing in weight, kerosene distillate, gas oil, and lubricating distillate. There finally remains a residuum in the still which may be fuel oil or petroleum coke according to the degree of heating. The pipe from the look box is manifolded into a number of pipe lines leading to different run-down tanks so that by opening and closing the proper valves the stream may be directed first to one tank and then to another according to the properties roughly determined by the still man. The usual basis of this separation is that of gravity determined in a few seconds by means of an instrument, a hydrometer, which floats in the liquid to different depths depending upon the density of the liquid.

GASOLINE.

The first fraction from the crude oil, for convenience called crude benzine, is pumped from the run-down tank to a specially constructed tank, known as an agitator. Most agitators have a capacity of 1000 to 2000 barrels. The agitator is provided with means for mixing the liquids, and while formerly paddles and other devices were used, it is now the common practice to mix or agitate by means of compressed air.

While the charge is being agitated, strong sulfuric acid is added.[2] The quantity of acid used may vary from one to six pounds per barrel of product treated according to its condition and the specific results desired. The benzine is then washed free from acid by showering water through it. Then, in order to be very certain that no acid remains, and to remove certain sulfur compounds, it is washed with dilute cautic soda.

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[1] The barrel unit in the petroleum industry is usually 42 gallons, but there is a tendency toward the unit of 50 gallons.

[2] In the Mid-continent field oil, sulfuric acid of 66° Baume is used.

The treated benzine is pumped to a steam still and re-distilled. The vapors may be led through special towers which serve to divide them while slightly cooling and the resulting streams may be further separated in the receiving house. In this manner a series of streams are diverted from one tank to another and a number of finished gasolines produced. If a gasoline free from sulfur compounds is desired, it is treated in an agitator with a strong caustic soda solution which has been previously saturated with litharge. Free sulfur is then added to completely precipitate the sulfur compounds. The alkali is then removed by washing with water. Commercial gasolines may vary from 54 to 74° Baume in gravity, and should be free from color, have a good odor, initial boiling point between 100 and 140° F. and maximum boiling point, which is often termed end point, between 350 and 460° F.

NAPHTHA.

All of the treated benzine pumped into the steam still cannot be vaporized as gasoline because the density of the resulting liquid is too high. When the gravity falls below that of commercial gasoline a division or cut is made into the next finished product, commonly known as naphtha.

Naphtha may vary from 42 to 54° Baume in gravity, should have a good odor, be free from color and have a close distilling range. An ideal naphtha should begin to distill at about 200° F. and completely distill below 450° F.

KEROSENE.

Kerosene may be partially obtained from the kerosene fraction of the crude oil and an additional quantity from the bottoms or residue remaining in the still after the naphtha has been distilled. The purifying treatment is the same as that outlined for gasoline.

The best known kerosenes have a gravity of about 42° Baume, flash above 125° F. and do not ignite below 150° F. The color should be almost water white. The initial boiling point should be close to 350° F. and the end point below 600° F.

GAS OIL.

The fraction distilling over after the benzine and kerosene is known as gas oil. It derived its name from the fact that it was originally used in the manufacture of gas for illuminating purposes or for the enrichment of coal gas. Now, however, gas oil is used in the manufacture of synthetic gasoline and kerosene. These products are made by subjecting gas oil to a temperature of about 750° F. and a pressure above 60 lb. per sq. in. in pressure stills.

A 32 to 40° Baume gravity, yellow colored gas oil is usually obtained from crude oil. This has an initial boiling point of about 400° F. and an end point (maximum) of 730° F.

LUBRICATING OIL.

Lubricating oils are obtained from wax distillate, the fraction following the gas oil cut. The wax distillate has the following properties: gravity, 30.0 to 32.0° Baume; viscosity at 100° F., 55-70; cold test, 55 to 80° F.

The wax distillate is cooled and the solidified wax pressed out at a low temperature under a high pressure. The wax-free oil, known as "pressed distillate," is then reduced in a still to the desired viscosity lubricating stock. When reducing, considerable steam is used in the distillation in order to prevent the oil from "cracking" or as still men frequently say from "burning." Heavy benzine, gas oil, and light lubricating distillate are obtained as overhead products, the residue being the base for the heavy lubricating oil. The light lubricating distillate contains volatile products, which must be removed. This is performed by reducing as before with fire and steam to the viscosity specified.

The reduced lubricating stocks are further refined by treating and filtering. The oils are agitated, by means of air, with strong sulfuric acid in large agitators. It has been found that better results are obtained if the acid is added in small portions instead of adding the acid all at once. A small quantity, known as "water acid," usually one pound per barrel of oil treated, is added and agitated with the oil for a short time. The agitation is then discontinued and the acid sludge permitted to settle, after which it is drawn off. Then about four pounds of new acid known as the "first body acid" is agitated with the oil. The agitation is again stopped and the acid sludge drawn off. The larger portion of the acid, "second body acid" is then added. This quantity varies with the nature of the oil treated but is frequently four to ten pounds per barrel of oil. This is then agitated an hour or more with the oil, after which a sufficient quantity of water is added to coagulate the asphaltic material in the oil. This operation is known as "coking." The acid sludge is drawn off as quickly as possible and the asphaltic material or "coke" permitted to settle. If the proper quantity of water is not added the asphaltic material becomes finely divided or is "peppered" and is difficult to separate from the oil. The oil which is still acid is pumped into another agitator where it is neutralized with caustic soda, a 1 to 5° Baume solution being used. After the acid has been neutralized, the caustic soda is permitted to settle and is drawn off. The oil is then freed of moisture by heating to about 120 to 140° F., and then blowing with air until the oil is bright. During the neutralization, the oil sometimes becomes emulsified or is "soaped." The emulsion is often broken by heating or sometimes by heating and agitating with a demulsifying compound. The oil should be treated in such a manner that a minimum quantity of salts are formed during the process, as these cause the finished oil to have a poor emulsion test. The acid treatment removes considerable coloring matter, but frequently not enough to meet color specifications. The oil is then filtered through fuller's earth until the desired color is obtained. The filtering also improves the emulsion test. After filtering, the oil is ready for the market.

Refiners frequently manufacture two grades of lubricating oil, a light and a heavy oil. These oils generally have the following tests:

	LIGHT OIL.	HEAVY OIL.
Flash	330 – 400° F.	375 – 425° F.
Fire	400 – 460° F.	460 – 500° F.
Cold test	10 – 30° F.	20 – 35° F.
Viscosity at 100° F.	50 – 150	200 – 400
Color (N.P.A.)	2	3, dark red

All lubricating oils should have a fair emulsion test and a low carbon residue. Many purchasers of lubricating oils demand a light colored oil, but a good color does not necessarily signify a good lubricant.

WAX.

Paraffin wax is also obtained from the wax distillate cut. The wax distillate is cooled to about 7° F. in chillers by means of ammonia or a brine solution. The solidified mass is granulated and carried forward to the presses by a helicoid conveyor. The wax is then separated from the oil by forcing the cooled mass of oil and wax through filter presses under a high pressure, approximately 350 lb. per sq. in. The crude wax remains upon the canvas filter and the oil drops into the pan below.

The crude wax known as "slack wax" is removed from the press and conveyed to a tank where it is melted. The slack wax contains a large percentage of oil which must be removed. This is done by a process known as sweating. The "sweaters" are large shallow pans which contain wire screens a few inches above the bottom. Sufficient water is placed in the pan to cover the screen. The melted wax is then pumped on the water and permitted to solidify slowly. When solid, the water is drawn off at the bottom of the pan, the cake of wax being supported by the screen. The temperature of the sweater room is gradually increased by means of steam in closed steam coils. The oil, known as "foots oil," first separates from the wax, followed by the low melting point or "intermediate wax." The wax from the sweater is known as "scale wax." The scale wax usually has a yellow color which is removed by treating and filtering. The scale wax is melted and treated with a few pounds of 66° Baume sulfuric acid, usually with one and three pounds in succession. The acid is drawn off and the remaining acid in the wax neutralized with 1 to 3° Baume caustic soda. The alkali is permitted to settle from the wax, the temperature being maintained at about 140° F. during the entire process. The melted wax is then filtered through fuller's earth to the desired color. Wax has a specific gravity of about 0.9, a melting point of approximately 122°/124° F., a 1.0 color on a 6 in. Lovibond cell and not more than 1 per cent of oil and moisture.

WAX TAILINGS.

After the wax distillate has been removed from the crude oil, a fraction containing considerable amorphous wax, known as "wax tailings" distills over. The wax tailings are not passed through the condenser coils but are permitted to pass directly from the vapor line to a small tank known as the "wax pot." They are of practically no value, being simply blended with fuel oil. Attempts have been made to use them for various purposes. They are used in waterproofing compounds and in making rubber substitutes.

COKE.

Coke is the residue remaining in the still after all the volatile products have been removed. It has a high B.T.U. value, sometimes as high as 15,000 B.T.U. It is used in making battery and arc-light carbon and in metallurgical operations.

FUEL OIL.

The composition of fuel oil varies widely. The refiner who runs a skimming plant simply removes the gasoline, kerosene and gas oil from the crude oil and sells the remainder as fuel oil. At times when there is little demand for gas oil, he does not even take the trouble to remove this. Other refiners remove the wax distillate. The large refiner also sells as fuel oil, the bottoms left in the pressure stills after the gas oil has been cracked.

The gravity of fuel oil ranges from 14 to 30° Baume depending upon the number of products removed from the crude. The B.T.U. value varies from 18,000 to 19,000 B.T.U. The sulfur content of Mid-continent fuel oils is rarely more than 0.5 per cent. A high grade fuel oil should not contain more than a trace of sand, carbon and water.

CYLINDER STOCK.

Crude oil that contains the proper lubricating base, often bright green in color, is distilled with considerable steam in order that a heavy oil may be obtained after the gas oil and a portion of the wax distillate have been removed. This product is known as cylinder stock. Cylinder stock should have a high flash and fire test; the color should be green to red, not brown nor black. If a brighter color is desired, the oil is treated and filtered.

Cylinder stocks from Mid-continent crude oils usually have the following tests:

Flash	500 – 600° F.
Fire	575 – 700° F.
Cold Test	40 – 70° F.
Viscosity at 212° F.	130 – 250
Color	Green

PETROLATUM.

Petrolatum is obtained by diluting cylinder stock with naphtha and then chilling or "cold settling" until the amorphous wax or petrolatum separates. The liquid is drawn off after which the naphtha, remaining in the petrolatum, is distilled off in a steam still. The residue is usually dark in color. If a brighter color is desired, a naphtha solution of the petrolatum is treated and filtered before steam stilling.

Centrifugal Process.—Methods have been developed for separating petrolatum from the cold cylinder stock by means of centrifugal force: the machines operating often around 15,000 r.p.m., handling the cold oil, the entire apparatus being in a room maintained at a low temperature. The machines used for this purpose are operated on the same principle as those employed for separating cream from whole milk.

Petroleum obtained from different parts of the world varies in quality, and crude oils from different wells in the same pool seldom have exactly the same characteristics; so it is, therefore, not surprising to find that similar products from petroleum, while exhibiting common general properties, may quite easily, upon close examination, be distinguished from each other. A petroleum refiner seldom attempts to make his products like those made by another refiner. The effort is always toward a product with individuality. The output of a refinery this year is not absolutely identical with that of last year.

Within the last few years the processes for the refining of petroleum have been so improved that the products from different refineries while varying often in some particulars, have general characteristics which come within comparatively narrow ranges. The rule-of-thumb methods of former days have been replaced by operations based on scientific facts with the result that under technical supervision there is much less waste and greater output of uniform products. The scientific management of refineries and the handling of petroleum products has to rely on methods of analyses and testing; consequently there is a demand, probably the greatest need of the petroleum industry today, for uniformity in methods of testing—a work which has been left to this Society, to which the petroleum industry is greatly indebted.

PROBLEMS INVOLVED IN THE DEVELOPMENT OF SPECIFICATIONS FOR MOTOR GASOLINE.[1]

By E. W. Dean.

Introduction.

One of the vital problems associated with the production, sale, and utilization of motor gasoline is the development of practical specifications for quality and grade. The importance of this problem has been thoroughly recognized and the use of gasoline specifications is already an established practice. Large users, among which the Federal Government is a notable example, have adopted more or less complete sets of requirements for grades and quality of motor fuel. Transactions within the petroleum industry frequently involve specifications and last, but not least important, is the fact that a number of state and municipal legislative bodies have adopted or are considering the adoption of regulations controlling the quality of motor fuel dispensed to the general public.

The subject of employing and enforcing gasoline specifications is too broad to warrant discussion as a whole in this paper. It seems most important to indicate the status of present knowledge regarding the practical requirements and to point out necessary developments for the future.

Outline of the General Problem of Developing Gasoline Specifications.

The majority of the problems involved in the development of practical specifications for motor gasoline can be grouped in three general classes, as follows:

1. The recognition of essential properties;
2. Definition of essential properties in terms of adequate laboratory tests; and
3. The adoption of limits that express satisfactory quality in terms of the accepted laboratory tests.

General Properties of Satisfactory Motor Gasoline.

The following list of requirements is believed to indicate the general properties of satisfactory motor gasoline:

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[1] Published with the permission of the Director, U. S. Bureau of Mines.

1. Motor gasoline should not be unnecessarily dangerous in storage and handling and should not be subject to excessive evaporation losses.

2. Motor gasoline should not contain solid or non-combustible material.

3. Motor gasoline should be free from constituents that corrode or injure the parts of the equipment in which it is stored or used.

4. Motor gasoline should have a minimum content of constituents that tend to form solid or gummy deposits either in storage receptacles or in internal combustion engines.

5. Neither motor gasoline nor its products of combustion should possess markedly disagreeable odors.

6. Motor gasoline should have a properly limited and balanced range of volatility.

LABORATORY TESTS DEFINING ESSENTIAL PROPERTIES.

1. *Danger in Storage and Handling and Evaporation Losses.*—There is no question as to the desirability of including in specifications a clause that will preclude the transportation, sale, and use of gasoline that is unnecessarily dangerous and that is subject to excessive losses in storage and handling. The accuracy and adequacy of the present vapor pressure test[1] is, however, not above question and there is an unquestionable necessity for its improvement. The author understands that a modification of this test is being studied at the present time. The particular property under consideration can probably be controlled by the use of properly selected limitations based on results of the conventional distillation analysis, but it seems that this relatively elaborate procedure cannot be employed under the conditions existing when it is usually necessary to test gasoline for safety in shipment.

2. *Solid or Non-Combustible Material.*—The presence of solid or non-combustible material can be determined by optical inspection of a properly taken sample. Gasoline should, of course, be perfectly transparent and homogeneous.

3. *Corrosive Constituents.*—The problem of testing gasoline for corrosive constituents is one that cannot be adequately discussed in the present paper. There is a notable lack of information regarding the causes and mechanism of this phenomenon and it is not believed

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[1] Report of the Chief Inspector of the Bureau of the Safe Transportation of Explosives and Other Dangerous Articles, February, 1916, pp. 27–30.

Dean, E. W. "Motor Gasoline, Properties, Laboratory Methods of Testing and Practical Specifications," Bureau of Mines, *Technical Paper No. 214*, pp. 26–27 (1919).

that any or all of the present tests furnish conclusive evidence. The acidity test[1] is believed to offer a reliable means of detecting one type of corrosive constituent. The copper-dish evaporation test[2] is not satisfactory for the examination of motor gasoline, but a corrosion test under consideration by the American Society for Testing Materials and involving the same general principle can undoubtedly be used to detect another type of corrosive constituents. In general, however, it appears that the problem of corrosive properties is one that deserves more careful investigation than it has received as yet. The author ventures to predict that a discussion of some elementary questions regarding the occurrence of corrosion caused by gasoline, the details of a satisfactory laboratory test or the balance between the relative costs of buying non-corroding gasoline or replacing the injured parts of motors, would demonstrate the existence of conflicting opinions and a notable lack of real knowledge.

4. *Constituents that Solidify or Form Gummy Deposits.*—One of the most troublesome phenomena in the operation of internal combustion engines is the occurrence in cylinders and manifolds of "carbon" deposits. These are sometimes attributed to the use of lubricating oil of improper grade or unsatisfactory quality, but a fair proportion of evidence seems to indicate that the gasoline is either directly or indirectly the offending agent. It is by no means certain that the entire cause of the trouble is failure to effect proper dispersion of the fuel in the air mixture which goes into cylinders.

There is at present no satisfactory laboratory test indicating whether or not a particular sample of gasoline has an undue tendency to deposit solid material either in the manifolds and cylinders of internal combustion engines or in storage tanks or pipe connections. The copper-dish evaporation test has a certain degree of application in this direction but it has been shown by some experiments[3] made in Bureau of Mines laboratories that it can be applied satisfactorily only to grades of gasoline (such as airplane gasoline) that can reasonably be expected to give no deposits. The test as at present outlined does not seem satisfactory to use with limits on the maximum allowable quantity of deposit.

It is believed that there is need of investigating this general problem and determining first whether or not there is need for a specific test for the property of forming solid deposits and second what this test should be. Work along this line has already been undertaken by the Bureau of Mines but the subject is so broad that it is believed that other research organizations can profitably give it attention with the hope that the sum of the knowledge derived may yield a satisfactory answer.

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[1] Bureau of Mines, *Technical Paper No. 214*, p. 17.

[2] Report of the Committee on Standardization of Petroleum Specifications, *Bulletin No.* 5, pp. 3–4 (1921).

Bureau of Mines, *Technical Paper No. 214*, p. 25

[3] Results not yet published.

5. *Odor.*—Good odor is an important but, fortunately, not absolutely essential property of motor gasoline. It is, of course, impossible to hope that a test for this property can ever be standardized or that laboratory operators will agree in their olfactory sensations for any except either very good or very bad products.

6. *Distillation Range.*—The important property of distillation range is one for which a satisfactory laboratory test has been developed and adopted. Some of the details of apparatus and procedure are still a fruitful subject for argument, but the tentative standard method to be submitted at this annual meeting of the Society represents the agreement and compromises of men and organizations that have had the benefit of a very considerable amount of practical experience with the testing of gasoline.

SPECIFICATION LIMITS.

A complete discussion of specification limits for essential properties cannot be attempted in the present paper on account of the existing deficiencies in laboratory methods of testing. The subsequent section will therefore deal principally with the matter of distillation range which is generally recognized as of most immediate importance.

The most generally familiar set of gasoline specifications is that adopted by the Committee on Standardization of Petroleum Specifications and published in Bulletin No. 5 of this committee, issued under date of December 29, 1920. The specifications for motor gasoline printed on pages 42 and 43 include requirements for distillation ranges that place maximum limits on the temperatures read for the first drop, 20-per-cent mark, 50-per-cent mark, 90-per-cent mark and dry point. The particular points selected for specification limits were carefully chosen and have not apparently been subject to particular criticism. The actual temperature limits for the first drop, 20-per-cent point, and 50-per-cent point seem likewise to be reasonably satisfactory both to producers and consumers of motor gasoline. The limits for the 90-per-cent mark and the dry point are the ones concerning which authorities and alleged authorities are in disagreement and which can be profitably discussed in the present connection.

A great number of refiners have discovered that they can produce gasoline which satisfies the dry-point clause with an ample margin of safety and still fails to meet the 90-per-cent point requirement. This detail has been regarded as a serious flaw in the specifications and is so fruitful a source of argument that the author takes this occasion to point out the significance of this apparent lack of balance in the two limits. Determinations of dry point have been and probably still are likely to involve a considerable possibility or disagreement between the results reported by different operators. The 90-per-cent mark, on the other hand, is relatively easy to check. With this fact in view the members of the specifications committee thought it advisable to make the 90-per-cent mark the effective upper distillation limit and use the end point limit simply as insurance against careless or inefficient refining methods. The apparent discrepancy between these limits is, therefore, intentional and, on the basis of the evidence considered by the committee, justifiable.

A more important difference of opinion concerns the actual limits, of which, as has just been indicated, the 90-per-cent mark is usually the controlling one. A number of representatives of the refining industry have claimed that this is too low and therefore a detrimental influence on account of the present economic necessity of securing maximum yields of motor fuel from an inelastic supply of crude petroleum. Individual users are more or less inclined to the opinion that all present-day gasoline is unsatisfactory and that some products are worse than others. The most intelligent representatives of the consuming public are perhaps the men who design and supervise the manufacture of internal combustion engines and their majority opinion seems to be that gasoline meeting the present government specifications may contain appreciable percentages of constituents that are not efficiently utilized by the average engine.

The author cannot venture his opinion as to the relative merits of these opposing views and must, therefore, point out that the government specification is actually a compromise and not the result of biased views or ignorance. The following suggestions are, however, offered as an indication of the basic principles that should cover the selection of limits for any specification that is likely to receive widespread recognition as a standard for the quality of motor gasoline:

1. Specification limits should be selected as an agreement or at least a compromise between the views of thoroughly representative groups of authorities from the producers and the users.

2. Reasonable uniformity should be maintained in the quality of the gasoline produced by different refining companies and in dif-

ferent parts of the country. The influence of the law of supply and demand should be reflected in the price of the commodity rather than its quality.

3. Radical changes in the general quality of motor gasoline should, if possible, be agreed on and announced a reasonable time in advance of the date when the modification is to be made effective. This does not concern the normal seasonal variation in quality but rather such changes as are likely to affect the efficiency of the average existing motor. If such an arrangement could be effected it would be possible for automotive engineers to design and build motors to "fit" a known quality of gasoline and would also permit the development of supplementary devices to improve the operating efficiency of engines already in use.

These suggestions obviously indicate the necessity of cooperation between representatives of the producers and consumers. Such cooperative effort is already being organized and, needless to say, the Bureau of Mines commends all possible activity in its behalf.

IMPROVEMENTS IN APPARATUS FOR TESTING PETROLEUM PRODUCTS.

BY T. G. DELBRIDGE.

The necessity for making hundreds of tests daily in a single petroleum refinery laboratory is a remarkably efficient incentive to a search for improvements in the apparatus used. Unfortunately, many laboratories are still inclined to throw a veil of secrecy about their individual devices. Such reticence is not based on sound judgment. For the purpose of stimulating a freer exchange of ideas on the subject it has appeared proper to illustrate and describe some of the apparatus developed in the laboratories of The Atlantic Refining Co.

Fig. 1 shows the Nichols Gravity Apparatus devised by H. M. Nichols. It consists of a number of vertical brass cylinders of diameter and length suitable for the hydrometers used. These are supported by $\frac{1}{4}$-in. draining lines provided with stop cocks. The two end cylinders have also a pet cock for the recovery of those samples which are to be saved. An overflow trough adds rigidity to the apparatus and also provides a convenient rack in which hydrometers and thermometers may be laid when not in use. In using this apparatus a cylinder which has drained thoroughly is selected, stop cock is closed and the cylinder completely filled with the oil to be tested. The temperature is taken in the usual manner and the hydrometer immersed so that in coming to rest it causes the oil to overflow. The hydrometer reading is then made with the cylinder full of oil. Under these conditions no meniscus is observed and very accurate readings can be obtained even on the blackest oils. The apparatus has proven extremely satisfactory where gravity is a routine test on hundreds of samples of oil and the advantages are considered to be ease in reading the hydrometer, saving in labor, in breakage and in keeping work tables clean.

Fig. 2 shows the Atlantic Gravity-Temperature Corrector consisting of a printed correction chart mounted on a horizontal cylinder which can be rotated on its axis within a housing having a longitudinal slot just wide enough to show one horizontal row of figures on the chart. Just above this slot is a paper scale on which are printed figures denoting "observed gravities," both slot and scale being covered with glass for protection from dirt. Observed temperatures are printed in red on each side of the rotating chart.

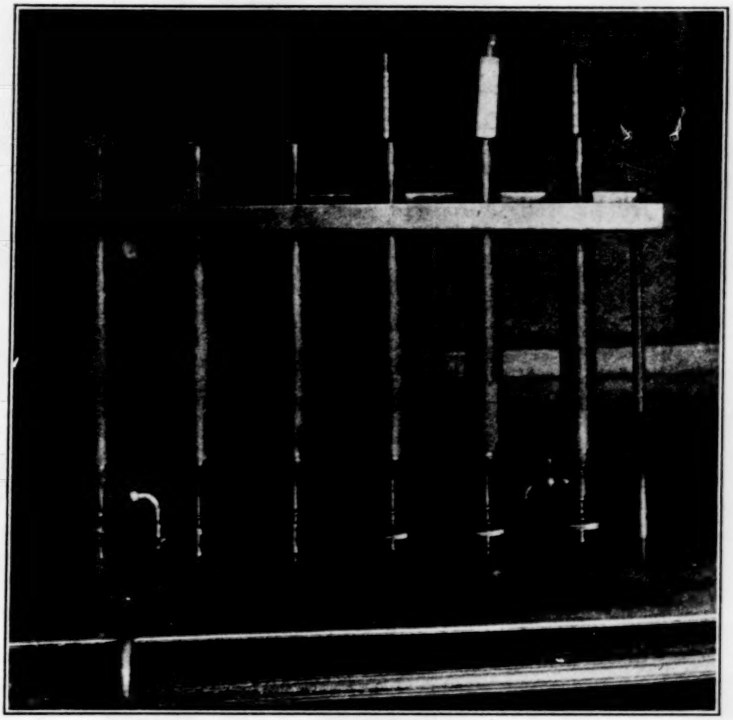


FIG. 1.—Nichols Gravity Apparatus.

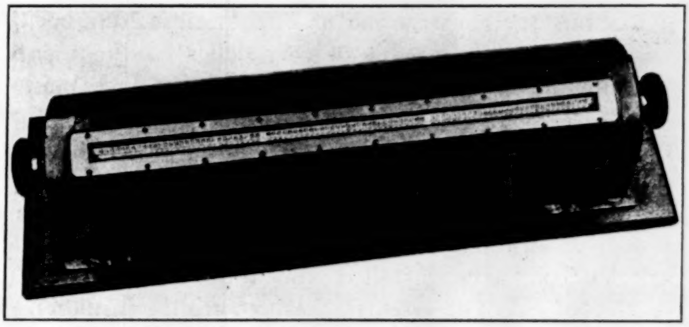


FIG. 2.—Atlantic Gravity-Temperature Corrector.

In using the Corrector the cylinder is turned until the proper observed temperature appears in the slot. This brings into view throughout the length of the slot the corrected gravity at 60° F. directly below each observed gravity read on the upper scale. This device eliminates the possibility of reading in the wrong line or column as is frequently done in the ordinary tables even by experienced operators. The figures on the chart indicating 0°.1 Baumé as well as figures for temperatures are printed in red, all others in black. A suitable base on the Corrector makes it possible to set the apparatus on the work table or to fasten it on a wall as may be more convenient.

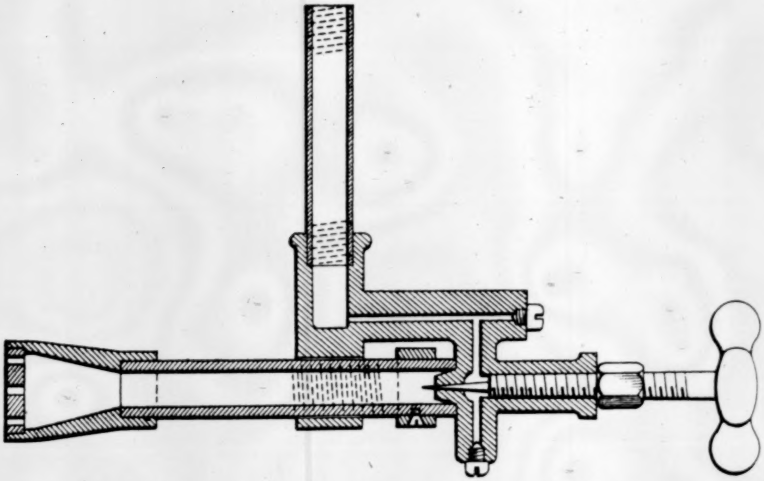


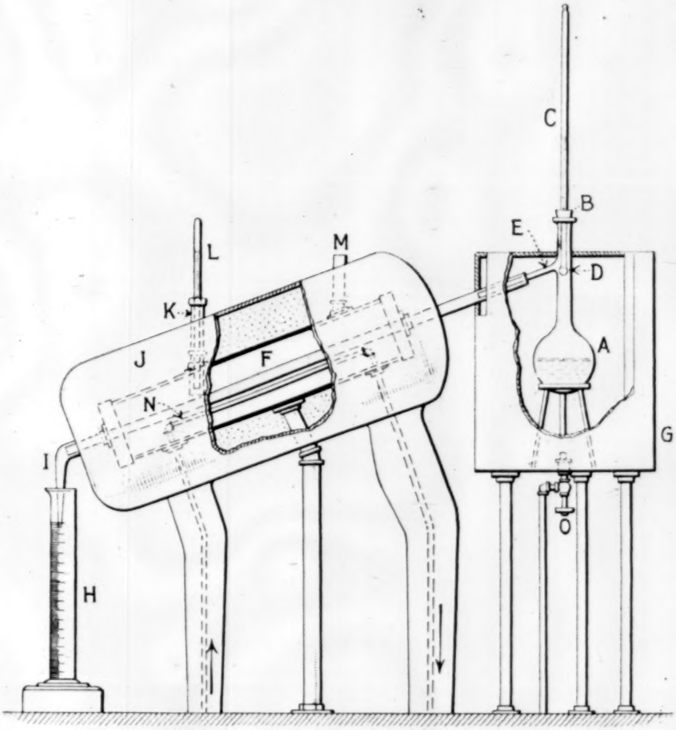
FIG. 3.—The Atlantic Refining Co. Gas Burner.

Fig. 3 shows the construction of The Atlantic Refining Co. Gas Burner. This burner is capable of very delicate adjustment and is especially valuable for assay distillations and for flash point determinations.

Fig. 4 shows the details of an End Point Distillation Apparatus equipped with a condenser cooled by chilled brine.

Fig. 5 shows the same apparatus insulated and ready for use.

Fig. 6 gives an interesting view of the assembly of three Saybolt Universal Viscosimeters installed for routine determinations of viscosity at 100° F. The essential features are the insulated jackets, the individual rotating vertical paddles operated from a small line shaft, the heating device which is a carbon filament electric bulb immersed in the water and controlled by a 4-point rheostat. This figure also shows one form of an electrically operated second counter which has practically displaced the ordinary stopwatch in The Atlantic Refining Co. laboratories.



A Flask.
B Cork.
C Distillation Thermometer.
D Thermometer Bulb.
E Vapor Outlet.
F Condenser.
G Hood.
H Receiving Cylinder.
I Adapter.
J Condenser Jacket.
K Thermometer Well.
L Condenser Thermometer.
M Condenser Fitting Opening.
N Coil for Chilling Medium.
O Burner.

FIG. 4.—End Point Distillation Apparatus.

Fig. 7 shows the Nichols Paraffin Wax Melting Point Recorder consisting of an oscillating trough and a very sensitive recording thermometer. The chart has 4 sectors each representing 15 minutes of time, the maximum required for any melting point. Such chart

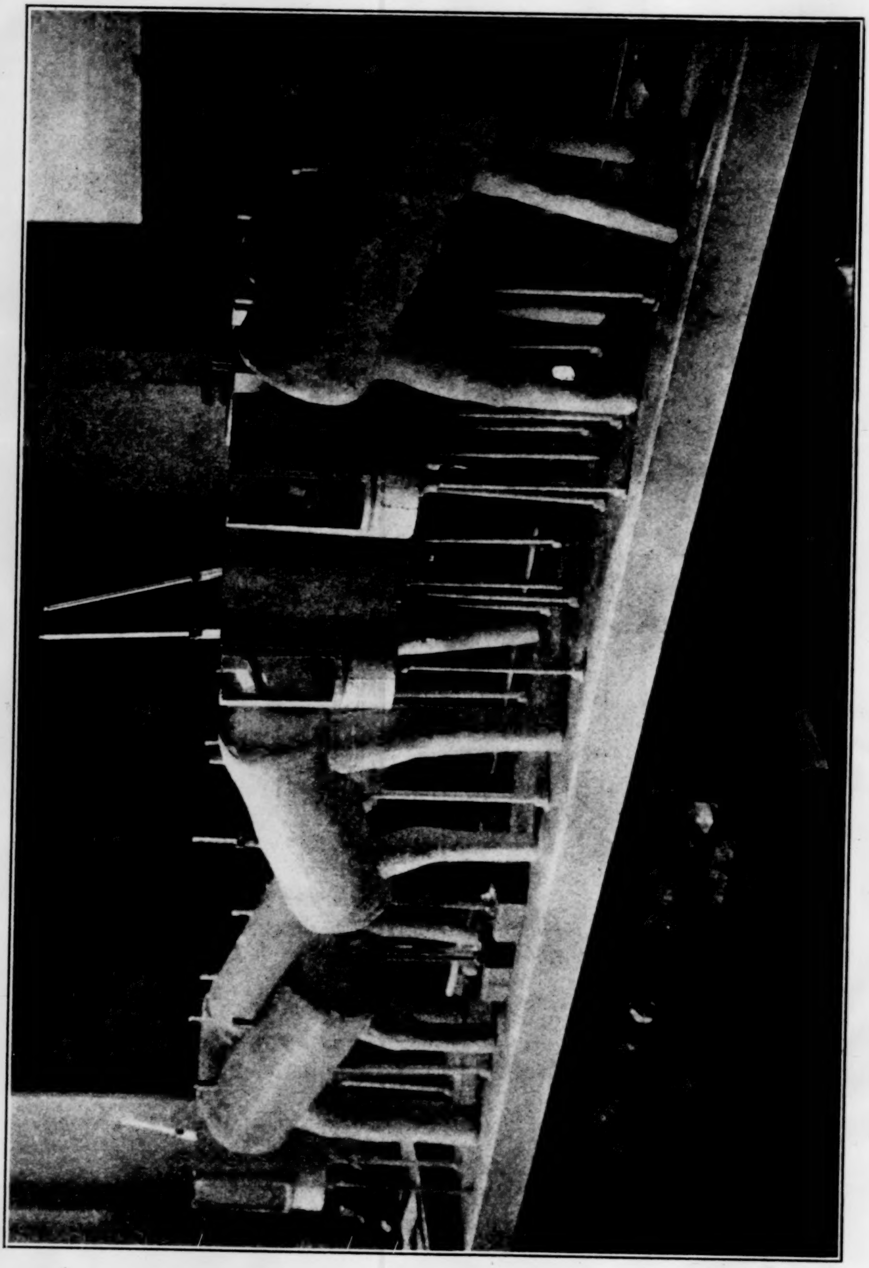


FIG. 5.—Distillation Apparatus Assembly.

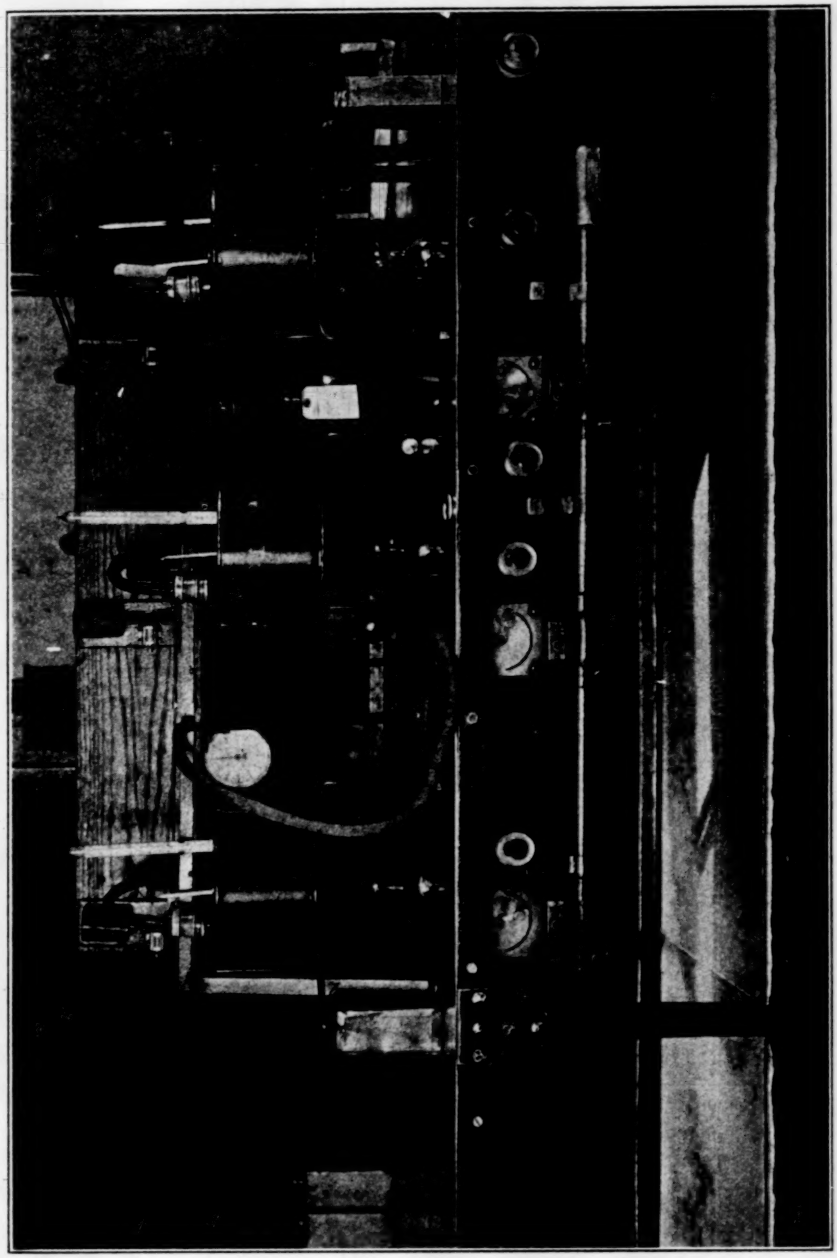


FIG. 6.—Saybolt Universal Viscosimeters.

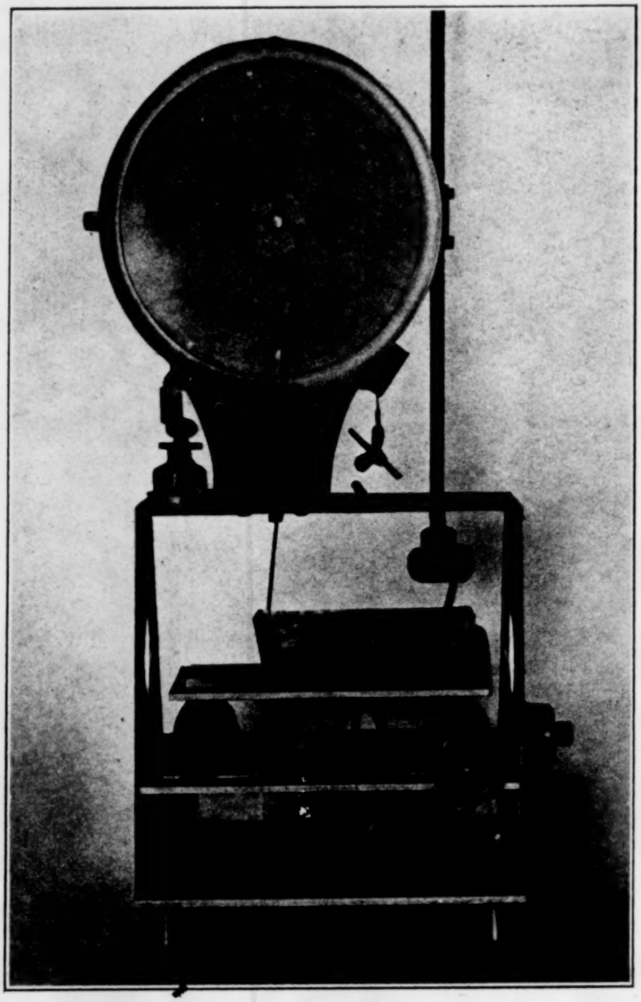
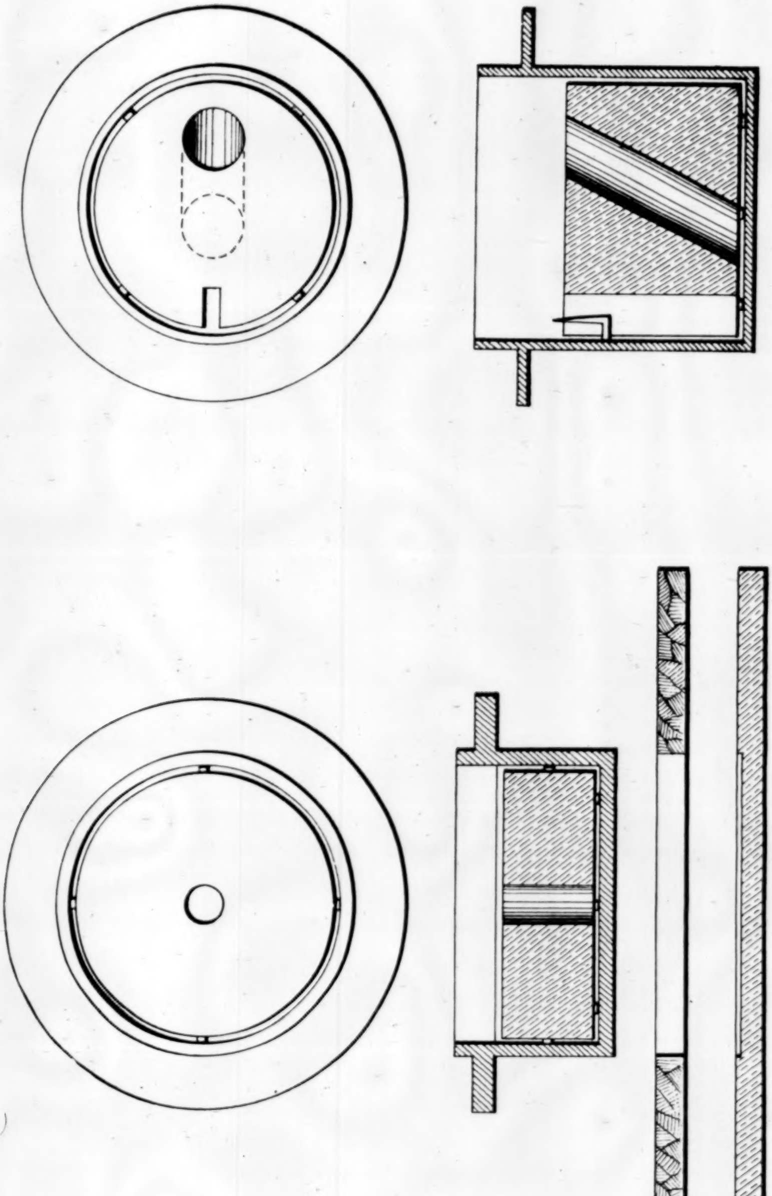


FIG. 7.—Nichols Paraffin Wax Melting Point Recorder.



(a) Cleveland Open Cup.

(b) Abel Cup.

FIG. 8.—Flash Adapters.

may be used for four separate determinations and may be filed as the original record after marking the proper identifications.

Fig. 8 shows the so-called "Flash Adapter" devised by C. H. Osmond and V. R. Abrams,[1] by means of which it is possible to take fairly accurate flash point determinations on 20-cc. samples of oil, most of the cup being filled by the adapter as shown.

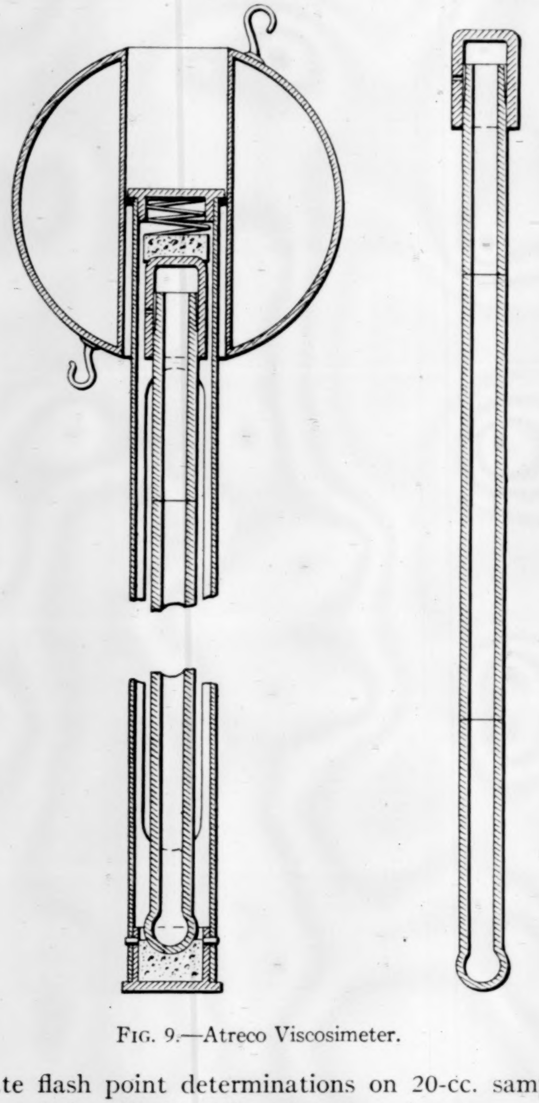


Fig. 9.—Atreco Viscosimeter.

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[1] Published by *The Atlantic Lubricator*, Vol. 4, No. 6, February, 1921.

TABLE I.

Oil.	Sayboldt Viscosity.	Time, seconds.	Factor.	Time, seconds.	Factor.
		Tube No. 1. Length,[1] 10 cm. Diameter, 5.2 mm. Length of Bubble, 17 mm.		Tube No. 5. Length, 9.4 cm. Diameter, 5.15 mm. Length of Bubble, 17 mm.	
1	86.8	8.4	10.33	9.6	9.04
2	145.6	14.1	10.32	16.2	9.00
3	229.0	22.2	10.31	25.5	9.00
4	475.2	46.1	10.31	52.7	9.02
		Tube No. 18. Length, 9.95 cm. Diameter, 5.2 mm. Length of Bubble, 17 mm.		Tube No. 19. Length, 9.95 cm. Diameter, 5.3 mm. Length of Bubble, 17 mm.	
5	92	7.9	11.64	7.3	12.60
6	146.6	12.6	11.63	11.6	12.63
7	234.6	20.1	11.66	18.5	12.68
8	475.2	40.8	11.64	37.6	12.63

[1] Length = Distance between etched lines.

TABLE II.

Oil.	Time, seconds.	Atreco Viscosity.	Saybolt Viscosity.	Difference.
Tube No. 1. Factor, 10.3				
1	8.4	86.5	86.8	0.3
2	14.1	145.2	145.6	0.4
3	22.2	228.7	229.0	0.3
4	46.1	474.8	475.2	0.4
9[1]	9.0	92.7	92.7	0.0
10[1]	10.8	111.2	111.3	0.1
11[1]	15.0	154.5	155.8	1.3
12[1]	17.3	178.2	178.3	0.1
Tube No. 5 Factor 9.00				
1	9.6	86.4	86.8	0.4
2	16.2	145.8	145.6	0.2
3	25.5	229.5	229.0	0.5
4	52.7	474.3	475.2	0.9
Tube No. 18. Factor, 11.64				
5	7.9	92.0	92.0	0.0
6	12.6	146.7	146.6	0.1
7	20.1	234.0	234.6	0.6
8	40.8	474.9	475.2	0.3
Tube No. 19. Factor 12.63				
5	7.3	92.2	92.0	0.2
6	11.6	146.5	146.6	0.1
7	18.5	233.7	234.6	0.9
8	37.6	474.9	475.2	0.3

[1] Compounded specially for test.

Fig. 9 shows the Atreco Viscosimeter devised by C. H. Osmond, V. R. Abrams and J. T. Kavanagh. This instrument permits determination of viscosity on 5 cc. samples of oil and direct conversion to Saybolt Universal viscosity. The operation consists of measuring the time required for an air bubble of definite size to rise through the body of oil confined in a glass tube of definite size and shape. By use of a factor, previously determined for each individual instrument, the Saybolt Universal viscosity may be calculated, provided this is not less than 85 seconds.

Table I shows results obtained in calibration of four Atreco Viscosimeter tubes for their Saybolt factors. Table II shows typical routine results on several oils by various Atreco Tubes.

In conclusion, attention is called to the need for greater publicity on the subject of special petroleum testing apparatus. It is hoped that this paper will encourage other laboratories to abandon a policy of secretiveness which cannot be justified.

STRESS-STRAIN MEASUREMENTS ON FILMS OF DRYING OILS, PAINTS AND VARNISHES.[1]

By Harley A. Nelson.

Introduction.

The physical properties of oxidizing mixtures of drying oils with pigments and gums, which are indicated and measured by their stress-strain diagrams, have not received the attention and study that their practical and theoretical importance would seem to merit. A paint or varnish is recognized as a material which, when finally in place, gives protection in proportion as it retains certain desirable properties despite the action of the weathering agents to which it is exposed. There may be argument as to just what properties are desirable, but there is no question as to the desirability at all times of a proper balance between elasticity and tensile strength, or a certain degree of toughness, retained over a maximum period of time. Hence, the development of rapid and easy methods for measuring by some empirical means, and a detailed study of these stress-strain properties under all conditions, must be considered necessary in the further development of the paint, varnish and allied industries.

Measurements of the stress-strain properties on films of paint are first referred to in connection with the Atlantic City and Pittsburgh Paint Test Fences,[2] and later described more fully by Gardner.[3] The instrument used, known as the Perry Filmometer, recorded the weight of mercury required to rupture a film of paint clamped between two rings, and measured the expansion of the film under this pressure. However, up to the present time, no detailed study has been made of the requirements for successful stress-strain measurements on oxidizing films, the factors that influence the results, and the characteristics of the resulting curves.

Films for Testing Purposes.

Films for testing are obtained by painting, spraying, or flowing the material on a tinned surface which has been previously amalgamated with mercury. Ordinary roofing tin can be used, the only requirements being a smooth surface and freedom from pinholes. Or, clean sheet iron itself may be surfaced with the tin amalgam by rubbing on along with the amalgam a small amount of dilute hydrochloric acid. Wet paint or varnish adheres very well to such surfaces, and, when dry, is easily removed without any forcing or distortion.

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[1] A contribution from the Research Laboratories of the New Jersey Zinc Co.

[2] Laboratory Study of Panels of Atlantic City and Pittsburgh Test Fences, *Bulletin No. 19*, Scientific Section, Paint Mfg. Assoc.

[3] H. A. Gardner, "Paint Technology and Tests," 1911.

The method of applying the film must be suited to the material under study. If the consistency is proper for spraying, this produces a very uniform film, whether done in one or more coats. Brushing on of paint is unsatisfactory, unless the "yield value" is low enough to permit the brush marks to flow out. Varnishes and enamels of high vehicle content are most easily flowed, and generally yield very satisfactory film specimens.

No absolute means have been found for controlling the thickness of film specimens, and producing films of a definite thickness resolves itself to a matter of "cut and try" depending on the skill and experience of the operator. A suitable working range for paint is a thickness of from 0.120 to 0.150 mm. Varnishes can usually be best manipulated to yield films ranging from 0.090 to 0.100 mm. in thickness. It is important that for any one comparative test, the thickness of the specimens be kept nearly equal, and certain allowances made for unavoidable differences. These will be discussed later.

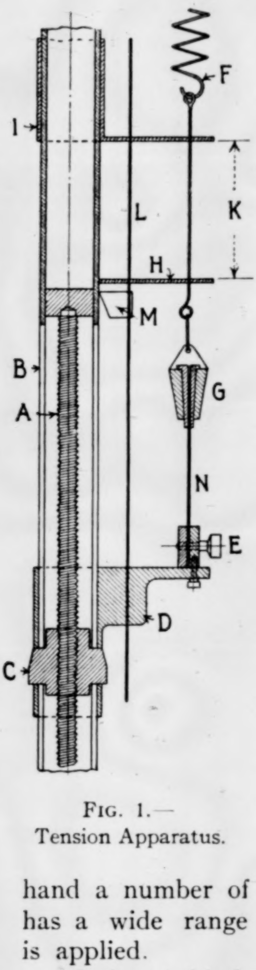

FIG. 1.—Tension Apparatus.

APPARATUS AND PROCEDURE.

The Tension Apparatus.—The ordinary helical spring, tempered to follow Hookes' law, is ideal for accurate application of the small loads that often must be used. By having at hand a number of these springs of varying strengths, the operator has a wide range for variations in the rate at which the load is applied.

It is on this basis that the instrument shown in Fig. 1 was developed. The power is supplied at the base by a $\frac{1}{16}$-h.p. motor connected with a sliding rheostat to provide a range of speeds. The screw *A* is fitted in the center of the hollow main standard *B*, and driven through a worm reduction gear to the motor. The standard is slotted over a greater part of its length to permit the split-nut *C*, actuated by the screw, to drive the moving platform *D*. Opening the split-nut permits free adjustment of the moving platform to any desired position. On this platform are mounted the lower grip *E*, for holding the specimen, and the extensometer attachment (shown in Fig. 2), both of which are detachable. The spiral spring *F* is so suspended that it is in alignment with the lower grip, and to it is attached, by a long wire hook, an aluminum grip *G*. The wire hook is provided with a stop *H*, which is caught by the sliding sleeve *I*. This sleeve follows the movable platform at a distance determined by an adjustable hook. It is evident that the distance *K* between this sliding sleeve and the stop on the wire hook must take care of the elongation of the specimen, and the length of the wire hook must be calculated

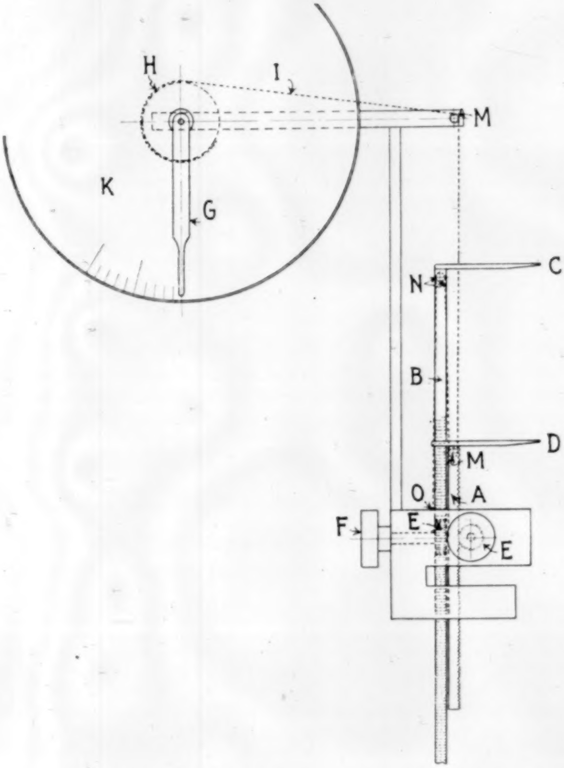

FIG. 2.—Extensometer Attachment.

accordingly. A taut piano wire L extends the full length of the instrument. On this wire is a celluloid marker M, which moves down with H, and, when the break occurs, remains fixed to indicate the ultimate load, the spring having been previously calibrated in grams according to the millimeter scale etched on the side of the standard B.

The Extensometer.—The extensometer attachment shown in Fig. 2 is mounted on the movable platform. It consists of two movable racks (A and B) carrying the pointers C and D and actuated by the pinions E and the thumb screws F. Reading the instrument is facilitated by the indicator G mounted on a shaft extending to the small drum (H) back of the dial K. A strong silk cord L is wound on the drum and passes over the pulley M in line with the very small pulley M mounted on the back of the rack A. Thence, it passes up and over a similar pulley N on the rack B, and finally down to be fastened at O. The compensating action of this cord renders the indicator very sensitive to any changes in the distance between the two pointers, which are set at predetermined points on the test specimens. The dial is calibrated to read directly the percentage of the original distance between these marks represented by the elongation. An automatic penciling device, mounted on the indicator, facilitates taking successive readings, when a complete stress-strain diagram is wanted.

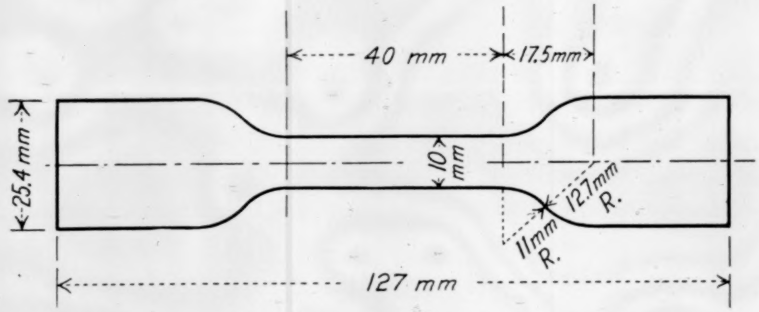

FIG. 3.—Form and Dimensions of Test Specimen.

The Grips.—The upper grip G (Fig. 1) is made of cast aluminum, and grips the samples between two wedge-shape sections, which are forced into a similar opening in the center of the block. The lower grip E is made of brass. Each jaw of the latter is covered with rubber in order to protect the specimen from any localized pressure of sharp edges.

The Die for Cutting Test Specimens.—The die selected for cutting test specimens, shown in Fig. 3, was modeled after that recommended by the Bureau of Standards for use in the testing of rubber,[1] with such modifications in dimensions as were found practicable. It should be made of tool-steel, carefully sharpened, and free from ragged edges, as the cut must be clean as possible. Mounting the die in an Arbor press as shown in Fig. 4 is very satisfactory. The cutting is done against a maple wood block, over which is laid a piece of ordinary cardboard. A strip of writing paper serves as a background for the film to facilitate handling and prevent possible injury.

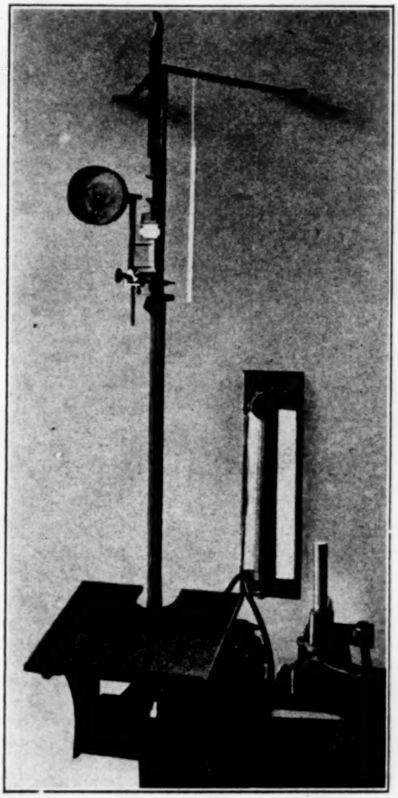

FIG. 4.—Stress-Strain Apparatus Complete with Extensometer and Test Specimen in Position for a Test. (Die mounted in Arbor Press shown in lower right-hand corner.)

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[1] *Circular No. 38*, U. S. Bureau of Standards.

The Procedure During a Test.—Fig. 4 shows the apparatus complete and ready for a test. Briefly stated, the procedure during a test is as follows: The thickness of the specimen is first determined as the average of about five readings taken along the length of the constricted area. The test specimen is then fitted into the upper grip, which is hung on the hook attached to the spring, and the moving platform adjusted to bring the lower grip into position. The alignment of the test specimen with the grips and spring should be as nearly perfect as possible. The extensometer is then fitted into its place on the platform, and the indicator set at the "zero" per cent mark. The pointers then indicate the places for the markings on the test specimen, for which two small dots made with ink will suffice (heavy markings with pen or pencil must be avoided). The sliding sleeve, which acts as a stop, is adjusted to the desired height, the rheostat of the motor adjusted to give the desired rate of loading, and the power finally applied by closing the split-nut on the moving platform. If a full stress-strain diagram is desired, an assistant follows the travel of the celluloid marker, and operates the marking mechanism of the extensometer at points previously selected. When the rupture occurs, the celluloid marker remains fixed to indicate the ultimate load. Except for special investigations, one full stress-strain diagram suffices to give accurate information as to the form of the curve, and the end points, that is, ultimate elongation and ultimate tensile strength, are checked by additional runs during which these alone are noted.

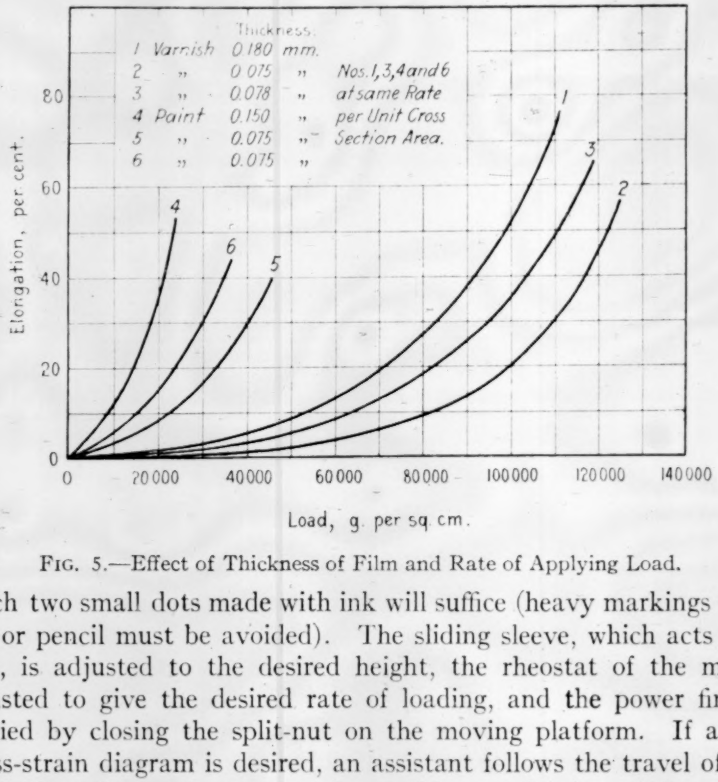

Fig. 5.—Effect of Thickness of Film and Rate of Applying Load.

FACTORS THAT INFLUENCE RESULTS.

Dimensions of Test Specimens.—The dimensions indicated in Fig. 3 were chosen after experimenting with dies of various lengths and widths. The length, 4 cm., between marks on the constricted area, is convenient and suffices for the accuracy required. The width of 1 cm. was accepted because of the added convenience of a unit width in making calculations. Repeated observations have indicated, moreover, that the width of the test specimen is not a factor in the numerical results of a test, provided the rate at which the load is applied be calculated to the same number of grams per square centimeter of cross-sectional area per minute.[1]

Thickness of Test Specimens.—Duplication of thickness over any considerable area is largely a matter of chance. The measurements recorded in Table I taken at random over the areas of three large sections of films of paint, varnish and enamel, demonstrate this fact.

TABLE I.—THICKNESSES OBSERVED OVER LARGE FILM AREAS.

THICKNESSES IN MILLIMETERS.						
PAINT.		VARNISH.			ENAMEL.	
0.110	0.120	0.110	0.115	0.115	0.115	0.120
0.110	0.135	0.110	0.110	0.120	0.120	0.125
0.120	0.140	0.110	0.117	0.115	0.117	0.115
0.130	0.130	0.110	0.105	0.110	0.125	0.120
0.125	0.120	0.110	0.120	0.112	0.120	0.120
0.100	0.110	0.113	0.125	0.117	0.120	0.120

As would be expected, films of varnish and enamel are more uniform.

The effects of variations in the average thickness of test specimens on stress-strain measurements arise from two causes. First, there is a difference in stage of oxidation of the films due to variations in the ratio of surface exposed to total volume. The second is due to changes in the rate of application of the load on the specimen, which, being a mechanical effect, can be corrected.

In Fig. 5, curves Nos. 1 and 2 represent two sections of a spar varnish film treated similarly throughout, of average thicknesses 0.180 and 0.075 mm. respectively. Curves Nos. 4 and 5 are of an ordinary combination paint, the films being 0.150 and 0.075 mm. average thickness, respectively. All of these curves were taken at the same grip speed. Curves Nos. 3 and 6, however, were taken after adjusting the grip speed for the thinner specimens so that the calculated rate in grams per unit cross-sectional area per minute is the same as that for the thicker specimen, or 15,000 g. per sq. cm. per min. Obviously, the differences between Nos. 1 and 3 or Nos. 4 and 6 are due to differences in the stages of oxidation attained by the specimens, but the variations between Nos. 2 and 3 or Nos. 5 and 6 can be avoided by proper adjustment of the grip speed.

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[1] The author has noted statements by rubber technologists indicating an increase both in ultimate elongation and ultimate tensile strength with narrow samples. These authors do not state so specifically, but it is assumed that tests were carried out at a constant rate of separation of the grips. This would mean, when finally reduced to basic units, that the load was being applied to the narrow specimen at a higher rate per unit cross-sectional area. For example, a specimen 5 mm. wide would be loaded just twice as fast as one 1 cm. wide, if the rate is calculated to grams per unit cross-sectional area per minute. Tests on specimens of rubber indicate that this is the case, and that specimens of differing widths show little variation if the rate is properly calculated.

Rate at Which Load is Applied.—According to the curves in Fig. 6, this test, when applied to oxidizing films, has the fault common to all dynamic tests on ordinary materials, namely, a variation in results with changes in the rate at which the load is applied. The rates of loading are calculated to the number of grams applied per unit cross-sectional area per minute.

Table II summarizes one of the several tests further illustrating the effect of variations in the rate of applying the load.

TABLE II.—EFFECT OF RATE OF APPLYING LOAD.

FILM.	RATE, G. PER SQ. CM. PER MIN.	ELONGATION, PER CENT.	TENSILE STRENGTH, G. PER SQ. CM.
Paint	100	23	38 700
Paint	13 400	19	42 700
Paint	47 000	17	49 500
Paint	52 000	15	49 000
Paint	60 000	15	49 000
Paint	2 000 000[a]	..	82 000
Paint	2 000 000[a]	..	79 000

This is in accord with what is generally found, namely (1) that the ultimate elongation varies inversely and (2) the ultimate tensile strength varies directly as the rate of application of the load, when calculated to load per unit cross-sectional area per minute.

In Fig. 7, ultimate tensile strengths are plotted against rates of loading. Inspection of these curves will lead to the following conclusions: (1) that the slopes of the curves vary directly as the ultimate tensile strength; (2) that within the most practical working range of 10,000 to 30,000 g. per sq. cm. per min., the relation is practically linear; and (3) that the ultimate tensile strength at infinitely slow rates may be rather easily obtained by extrapolation from observations made at three or four different rates.

Adjustments of the rate of loading are facilitated by the calibrated rheostat connected with the driving motor. The thickness and probable elongation of the specimen being known (the latter, if more accuracy is desired, by a rapid preliminary test), the grip speed can then be adjusted so as to give a loading rate at some predetermined figure. A rate of 15,000 g. per sq. cm. per min. has been found to be an optimum rate for ordinary tests.

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[a] Calculated to about this figure from time required to apply full load by rapid jerk.

Humidity and Temperature.—The great part that moisture plays in the physical properties of a film and the results of tension tests, cannot be fully appreciated without noting the curves in Fig. 8. Curve No. 1 represents a film of paint saturated with moisture in a humidor for 24 hours. No. 2 represents the same film after 24 hours in a desiccator over $CaCl_2$, while No. 3 was taken after exposure during the same time in a room carrying about 75 per cent humidity at 25° C. The moisture absorbed by films will vary in amounts, depending on the age of the film and its composition, the maximum so far found being about 2 per cent by weight.

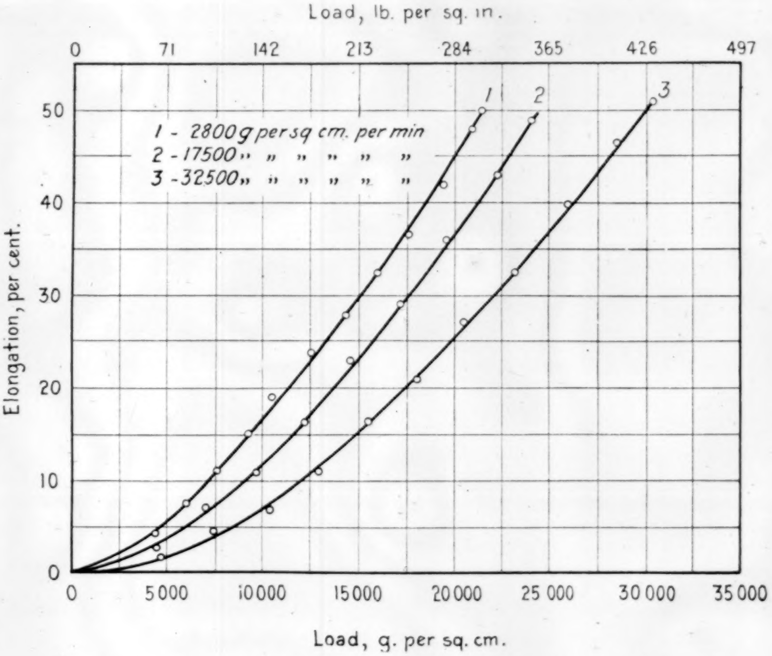

FIG. 6.—Effect of Change in Rate of Application of Load.

In order to eliminate in the most practical way any variable due to humidity and absorbed moisture, a scheme of desiccation for at least 24 hours has been adopted. This is most practical because (1) films at a low stage of oxidation, when at all moist, are flabby and inconvenient to handle; (2) an intermediate degree of humidity is uncertain and difficult to maintain without special equipment; and

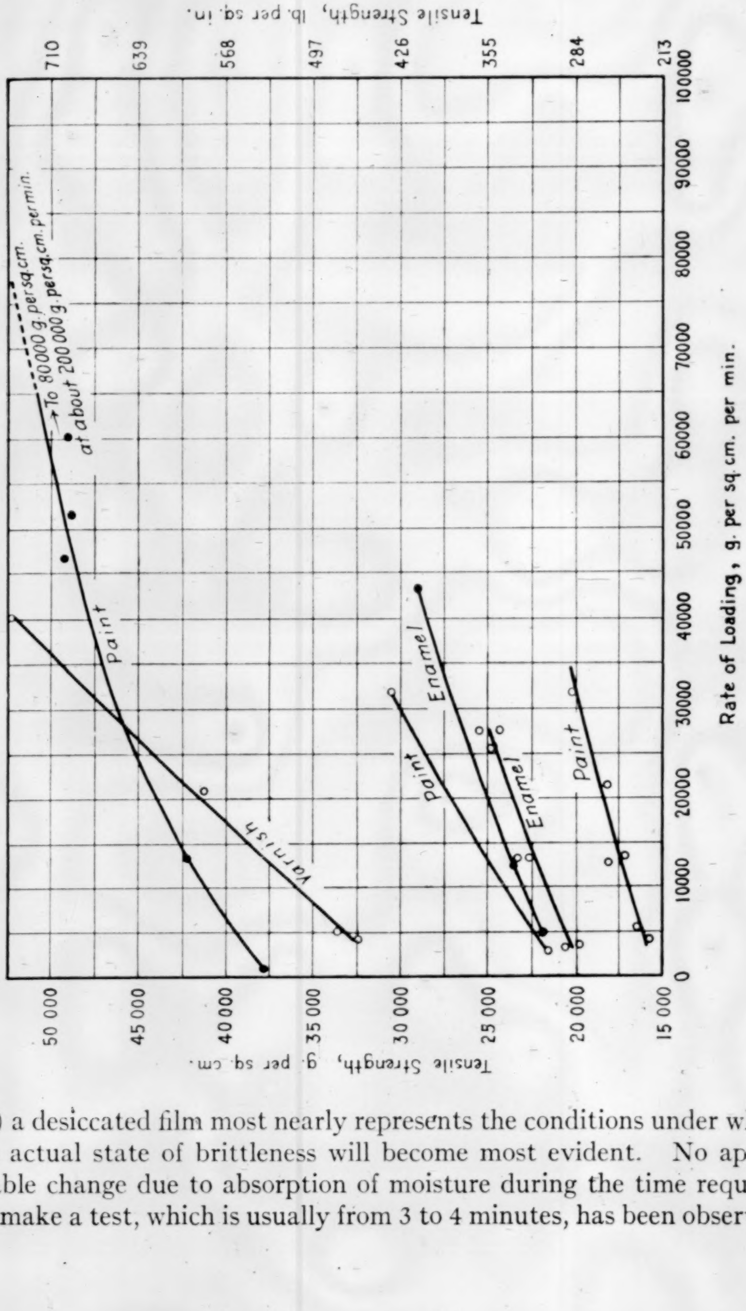

FIG. 7.—Effect of Rate of Applying Load on Tensile Strength.

(3) a desiccated film most nearly represents the conditions under which an actual state of brittleness will become most evident. No appreciable change due to absorption of moisture during the time required to make a test, which is usually from 3 to 4 minutes, has been observed.

There is much qualitative evidence that changes in temperature affect the physical properties of films to a considerable extent, but curves Nos. 4 and 5 in Figure 8 show this graphically. Curve No. 4 has been taken from specimens maintained in a desiccator at 20° C. while those represented by curve No. 5 were similarly treated at 25° C. For regular testing purposes, 25° C. has been accepted as a standard temperature for the desiccator and the atmosphere surrounding the instrument.

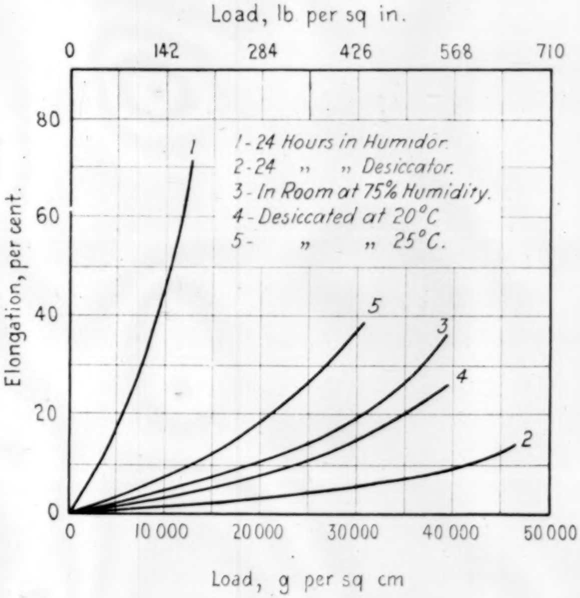

FIG. 8.—Moisture and Temperature Effects.

STUDY OF STRESS-STRAIN CURVES.

Typical Forms of Curves.—Films of various vehicle-pigment and vehicle-gum combinations have been studied with the object of finding the typical forms for the stress-strain curves of oxidizing films, and noting any similarities or dissimilarities. As paint and varnish mixtures have so often been referred to, in an off-hand way, as being similar to rubber in their properties, it was also interesting to determine just to what extent this holds true.

The curves in Fig. 9 are plotted so as to bring into prominence the typical forms that have been observed. Curve No. 1 is that of a vulcanized rubber, elongated barely to the point where the outward bend indicates increased resistance to distortion, thus exhibiting the characteristic *S* form. This portion of the curve is but a small part of the whole, the ultimate elongation and tensile strength on this sample being about 350 per cent and 1280 lb. per sq. in. (90,000 g. per sq. cm.), respectively.

Curves Nos. 2 and 3 are for films of two high-grade China wood oil varnishes recommended for exterior use under severe exposure. The samples were about two weeks old. No. 2 contained 45 per cent volatile and No. 3 contained 55 per cent volatile. No. 4 is of a common, fairly rapid drying, interior varnish about three days old, and is typical of this varnish and of several other linseed oil varnishes examined, although the ultimate points for others are often higher. No. 5 is of a soft film of paint, while No. 6 is the same paint after oxidation has been carried almost to the extreme by exposure to warm dry air. Curve No. 7 is typical of the best grade enamels examined after several months aging. Curves Nos. 8 and 9 are of kettle bodied linseed oil, No. 8 having been taken as soon as the film was sufficiently strong to permit handling, and No. 9 after about three months aging,

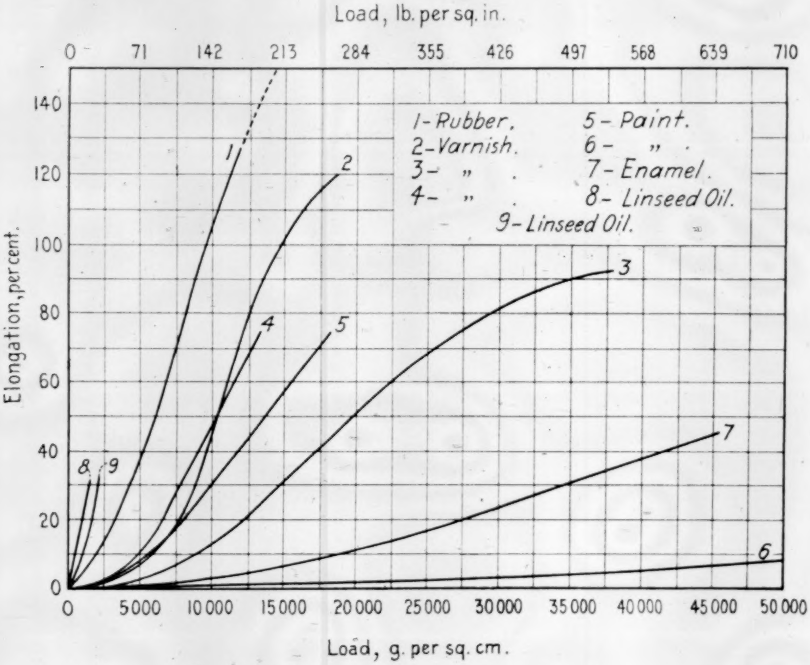

FIG. 9.—Typical Forms of Stress-Strain Curves.

part of the time at temperatures slightly above room temperature in order to hasten oxidation.

Mathematical Study of Typical Curves.—In Fig. 10 the curves of Fig. 9 are replotted, but with the logarithms of the stress-strain values as coordinates. Mathematically interpreted, the resulting straight lines mean that the original curves are of parabolic form according to the equation:

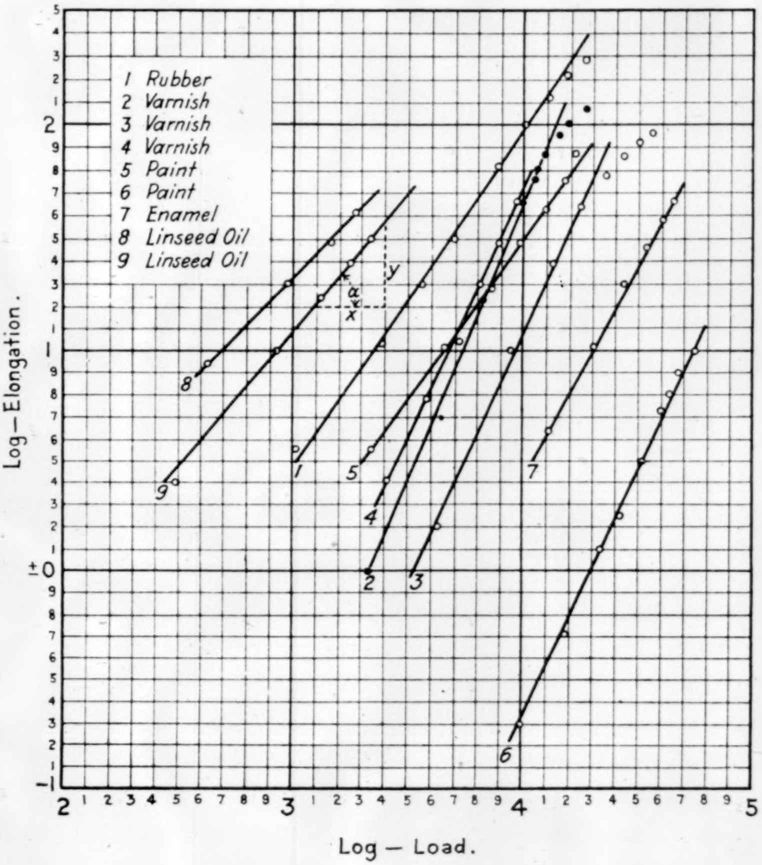

FIG. 10.—Typical Stress-Strain Curves Plotted to Logarithmic Scales.

$$y = ax^n \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

or, in this case

$$\text{Strain} = \text{Factor} \times \text{Stress}^n$$

The results plotted in Fig. 10 are typical of all oxidizing films handled under conditions of normal or slightly accelerated oxidation. In the cases of rubber, and varnishes Nos. 2 and 3, we are, of course, considering only that portion of the curve up to the outward bend, where they cease to follow the parabolic form.

For a parabolic curve, the value of the exponent n may be determined graphically by finding the slope of the straight line of the logarithmic plot. This slope is the tangent of the angle α (see curve No. 9) or, by definition,

$$\tan \alpha = \frac{y}{x} = \frac{18}{15}$$

$$n = 1.2$$

If n is first found from the logarithmic plot, a can be calculated as follows:

$$\begin{aligned} y &= ax^n \\ \log y &= \log a + n \log x \\ \log a &= \log y - n \log x \quad \ldots\ldots\ldots\ldots (2) \end{aligned}$$

or, as applied to some point on curve No. 9, such as 31 per cent elongation at 2150 g. per sq. cm.,

$$\log a = 1.50 - (1.2 \times 3.33) = -3.51$$

$$a = 0.0032$$

If now, the other curves in Fig. 10 are examined in order as the materials resist distortion, the following values are obtained for n and a in the equation $y = ax^n$:

	n	a
No. 8 Kettle Bodied Oil	1.0	0.0218
" 9 " " "	1.2	0.0032
" 1 Rubber	1.6	0.000 040
" 5 Paint	1.5	0.000 032
" 7 Enamel	1.8	0.000 000 23
" 6 Paint (highly oxidized)	2.2	0.000 000 000 38

That in the case of the oxidizing films, this variation in values for n and a depends upon the stage of oxidation attained by the film, is indicated by observed values as recorded in Table III.

In this respect the varnishes must for the present be considered apart from linseed oil alone, paints, and enamels, because, in general, they show high values for n, and low values for a, at very early stages. Also, curves for Nos. 2 and 3 are parabolic over only a portion of their full length, thus differing from No. 4, which is wholly parabolic, and yet shows values for *n* and *a* much the same as the former.

The varnish curves plotted in Figs. 9 and 10 give the following results:

	n	*a*
No. 2 Varnish	2.5	0.000 000 004 8
" 3 "	2.4	0.000 000 003 1
" 4 Interior Varnish	2.2	0.000 000 083

TABLE III.—VALUES OF *n* AND *a* FOR KETTLE BODIED LINSEED OIL, PAINTS AND ENAMELS AT INCREASING STAGES OF OXIDATION.

No.	Film of	*n*	*a*	Remarks.
1	Oil	1.0	0.021	Very soft film.
		1.2	0.003 7	Oxidized at room temp.
		1.7	0.000 023	Oxidized at 40° C.
2	Oil	1.0+	0.012	
		1.3	0.001 2	3 hr. under U. V Light
3	Paint	1.3	0.000 66	
		1.5	0.000 11	
		1.6	0.000 039	
4	Paint	1.25	0.000 67	
		1.67	0.000 001 8	
		2.09	0.000 000 005 7	
5	Paint	1.50	0.000 10	
		1.60	0.000 017	
		1.65	0.000 007	
6	Paint	1.5	0.000 035	
		2.5	0.000 000 000 017	Very highly oxidized.
7	Enamel	1.3	0.000 058	Fresh film.
		1.5	0.000 002 3	
		1.5+	0.000 001 5	

A carefully conducted series of tests on the two China wood oil varnishes represented by curves Nos. 2 and 3 gave results as tabulated in Table IV.

The values at hand for rubber do not cover a sufficiently wide range of vulcanizations to determine if the characteristics noted above hold in this case also. This is a point which will be considered in cooperation with the Rubber Section of this Laboratory. However, the following typical values were obtained:

TIME OF VULCANIZATION.	*n*	*a*
90 min.	1.4	0.000 36
120 "	1.4	0.000 26

Explanation of Observed Variations.—In order to assist in getting a picture of this observed simultaneous change in the values *a* and *n*, we may examine the curves in Fig. 11, which are a graphical representation of what can happen to the equation $y=ax^n$. First, it should be noted that as n increases, a being a constant, the angle within the curve at m approaches a right angle, until, if n ever reached infinity, it would become a right angle. This is the condition when the logarithmic plot of the curve in Fig. 10 becomes parallel to the y-axis. Such a supposition is purely hypothetical, but it would mean that the material, when stressed, does not elongate until a certain load is reached, when the entire elongation takes place instantaneously and without further load being applied.

If now the effects of changes in the value for a are examined, we note especially the tendency of the curve to drop, until, if a could ever become zero, a line along the x-axis would result.

As oxidation of the film proceeds, there results a progressive drop of the stress-strain curve toward the x-axis, as represented by decreasing values for a. At the same time, the angle within the curve at m is decreased with each increment of the exponent n, with the result that the final yield, represented by the upward part of the curves at m, rises more and more abruptly.

TABLE IV.—VALUES OF n AND a FOR EXTERIOR VARNISHES AT INCREASING STAGES OF OXIDATION.[1]

No.	Tensile Strength, g. per sq. cm.	n	a	Remarks.
1	13 700	1.5	0.000 076	Very soft film.
	19 200	1.7	0.000 008 7	
	35 200	2.2	0.000 000 008 7	
2	38 000	2.0	0.000 000 72	
	64 000	2.1	0.000 000 011	
	94 000	2.5	0.000 000 000 05	
	113 000	2.5	0.000 000 000 014	

All of the evidence at hand indicates that, within experimental error, the freshly formed linseed oil film approximates perfect elasticity. The stress-strain curve is a straight line with only slight evidence of a bend which indicates an elastic limit near the point of rupture. Or, according to the values in Table III, and the curves in Fig. 11, this is the condition when, in the equation $y=ax^n$, the variable exponent n approaches one as its limiting value.

Ultra-microscopic observations have not yet revealed the manner in which the solid phase makes its appearance when a drying oil takes on structure. However, for the present purpose we need only recognize the observed facts, (1) that in the presence of oxygen the entire process is normally progressive, (2) that the highly unsaturated compounds in the oil will undergo most rapid oxidation, and (3) that as oxidation proceeds, the film becomes more resistant to distortion and generally loses its high elastic property.

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[1] Oxidation accelerated at 40° C.

At first the solid phase will probably constitute but a small part of the whole, and the elasticity and extensive properties of the freshly formed structure are both very high, although its tenacity is of a low order. As oxidation proceeds, more solid phase is added to the structure. That already present advances a stage in oxidation, loses its high extensive properties, but becomes more tenacious. If the process is continued there results, then, a heterogeneous mass of semi-solid structure, part freshly formed and highly elastic, other parts with lower extensive properties, down to a certain amount of solid so highly oxidized that it will suffer but very little distortion without rupture.

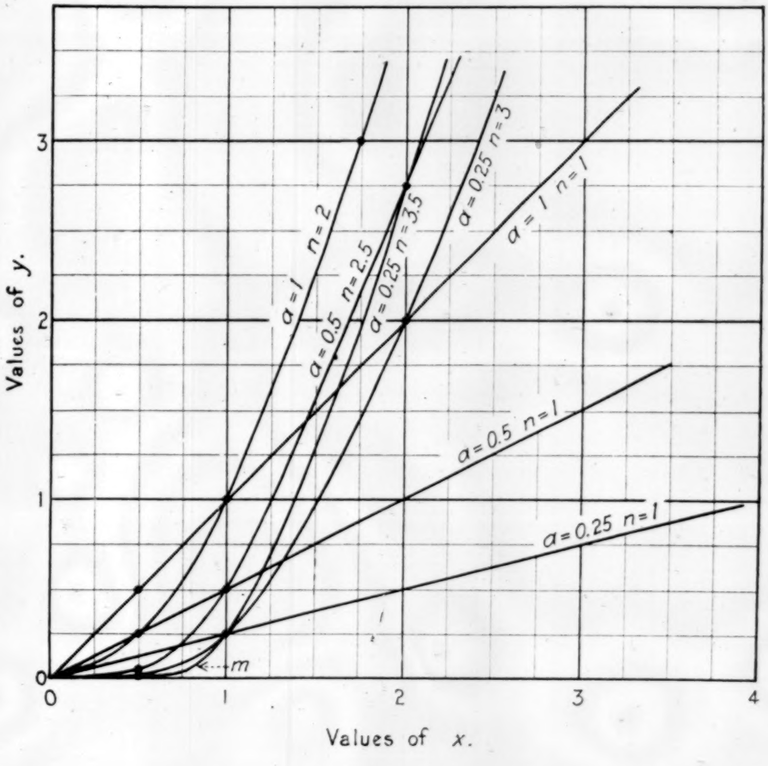
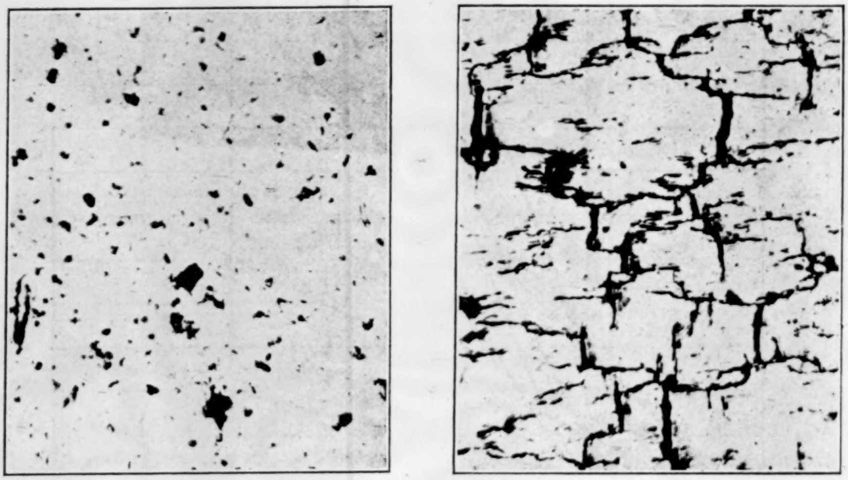


FIG. 11.—General Parabolic Equation: $y = ax^n$.

A steadily increasing load applied to such a structure must first encounter the resistance of the most highly oxidized material, which, in resisting distortion, directs the stress-strain curve along a path the slope of which is determined by the resistance encountered. But when the elastic limit of this portion has been passed, its resistance is lowered. Instantly the load is thrown on the remaining structure, which, being less resistant to distortion, yields more, with the result that the stress-strain curve is thrown upward and away from its original path. The whole process being continuous, at every step the stress-strain curve mounts more rapidly as the load tears away the last vestige of resistance presented by the finally very much overloaded structure that remains.



(*a*) Freshly Oxidized Film. (Dark spots are dust particles on the surface).

(*b*) Film Exposed 13 Hours to Ultraviolet Light.

FIG. 12.—Microphotographs of Linseed Oil Films, Stretched to Elongation of 10 per cent Above Original (×60).

On this basis, the increase in value for *n* as *a* decreases is to be expected. A certain portion of the mass, having reached a high stage of oxidation, is able through its increased tenacity to resist a greater load. But once overcome, the additional load is thrown with greater force on the remaining structure, which yields at an accelerated rate. The result is a sharper bend in the stress-strain curve, or a higher value for *n*.

At this point it is interesting to note the microphotographs shown as Fig. 12. Fig. 12(*a*) is of a freshly oxidized film of oil on which the values $n=1$ and $a=0.021$ were obtained. Fig. 12(*b*) is of the same film after 13 hours of accelerated oxidation under the ultra-violet light, then giving values $n=2.7$ and $a=0.000,000,007,5$. When the microphotographs were taken, each specimen was stretched 10 per cent over its original length. Note that (*a*) shows no visible signs of the distortion, but that (*b*), which is very resistant to slight distortion, disintegrates completely. Hence the rapid up-sweep of its stress-strain curve, and the abnormally high value for $n=2.7$.

The paint film may be considered in a similar manner. But the enormous surfaces exposed by the pigment, and the small interparticle distances, encourage rapid oxidation, with the result that the oxidized solid phase, in a few days, reaches a stage of oxidation which requires months on the part of a film of ordinary bodied linseed oil, unless under the influence of a catalyst. If the paint film ever approaches perfect elasticity and obeys Hooke's law, it must be very early in the stage of oxidation, indeed. As a matter of fact, the author has never observed a value for n below 1.2, and this figure soon increases to 1.4 or 1.5.

TABLE V.—ACTION OF PAINT FILM UNDER REPEATED STRESS.

MANIPULATION.	ELONGATION AT 6000 G. PER SQ. CM., PER CENT.	n	a
Loaded to 6000 g. per sq. cm........	40	1.6	0.000 039
Release and rest ½ hr...............	45	1.5	0.000 11
" " " " "...............	50	1.3	0.000 66

Varnish vehicles are usually so treated during the process of manufacture and incorporation, that extensive oxidation of a portion of the vehicle has already taken place. Also, the colloidal gums present expose tremendously greater surfaces to the oxidizing binder. Hence, the higher resistance to distortion at an early stage in the life of the film, or a higher value of n, accompanied by a relatively lower value for a, than in the case of paints. That this is the case, can be seen by comparing (Figs. 9 and 10) curve No. 4 for varnish with curve No. 5 for paint.

China wood oil exterior varnishes present a variation from the above. There appears the same increased resistance to distortion at early stages, and, also, the same accelerated distortion throughout the upward sweep of the stress-strain curve. But instead of breaking off short, the remaining structure, which has retained its high extensive properties, having submitted to distortion to the limit, shows sufficiently high tenacity, or structural property, to resist final rupture.

In this latter respect, then, these varnishes are more nearly analogous to rubber.

Further Evidence.—If films of paint are subjected to repeated stresses, the results are what would be expected according to the picture just presented, and are given in Table V.

Briefly, this suggests that more of the oxidized oil structure was ruptured with each distortion, and that the portion which was most highly oxidized, and originally offered the greatest resistance, suffered most, as evidenced by the decreasing value for n.

This gradual breaking down of the resistance of an oxidized film is further demonstrated by its action under a constant load, as indicated by Table VI.

TABLE VI.—ACTION OF FILMS UNDER CONSTANT LOAD.

Film.	Load, g. per sq. cm.	Elongation, per cent.	Remarks.
Linseed Oil ($n=1$)	200	4	Comes to rest within 5 min.
	400	8.2	" " " " 5 "
	1 000	20.5	" " " " "
	1 600	.....	Breaks instantly.
Paint ($n = 1.5$)	3 800	7.5	Attained in 30 min.
	6 300	18	" " 35 "
	6 300	34	" " 12 hr.
	6 300	42	" " 16 "[1]
Varnish (C. W. Oil) ($n = 2.4$)	5 000	2.5	To rest within 10 min.
	10 000	10	" " " 10 "
	20 000	62	" " " 2 hr.
	25 000	81	" " " 4 "
	30 000	105	Breaks at some time within 6 hr.[2]

[1] Sample is about to rupture at 42 per cent elongation. When released shows 7 per cent "set" at end of 5 hr. and 5 per cent at end of 18 hr. Normal breaking load under dynamic test 20,000 g. per sq. cm. at 38 per cent elongation.

[2] Regular dynamic tensile test gives an ultimate elongation of 97 per cent at 34,000 g. per sq. cm.

Effect of Variables on Values for a and n.—At this point it should also be made clear that the values of a and n are affected by variations in humidity, temperature, and rate of applying the load, and that the variations are in the same general direction as those due to oxidation. The reasons are evident. Moisture and heat soften the whole structure, and consequently the distortion can take place along a less abrupt curve. A slower rate of applying the load allows more time for the yield, with a similar result. Table VII is illustrative of this effect.

The above also suggests that from a plot of such values taken at various rates, it is comparatively easy to find, by extrapolation, the limiting values for n and a at infinitely slow rates. Such values, when found, would have the advantage of being true values from which the element of rate has been eliminated. Accordingly, the values in Table VII at infinitely slow rates become about 1.38 for n and 0.000,028 for a.

Elastic Limit.—All of the evidence and argument so far presented, makes the presence of any measurable elastic limit in films of highly oxidized linseed oil, and any paint or varnish seem improbable. At most, the true elastic limit can only be that of the most highly oxidized material, which will attain its elastic limit first.

The experiments described in Table VIII indicate that any true elastic limit in a film which has a value for n greater than one, must exist only at relatively low elongations.

Range of Values for n and a.—A question naturally arises as to whether the variables have any range of values which is characteristic for different types of material, that is, drying oils alone, drying oils with pigments, or drying oils with gums. It has already been pointed out that those in which part of the binder oxidizes rapidly apparently attain high values for n at an early stage. Whether, in the case of such materials, n has ever been nearly equal to one, is not known from direct experimental evidence. But the progressive nature of the process itself indicates that such is the case, and that, in all mixtures containing drying oils, n has at one time approached its limiting value of one, at which stage the stress-strain curve will also approach a straight line.

TABLE VII.—EFFECT OF VARYING RATES OF APPLICATION OF LOAD.

FILM.	RATE, G. PER SQ. CM. PER MIN.	n	a
Paint	2 800	1.40	0.000 026
	17 500	1.50	0.000 013
	32 500	1.70	0.000 001 2

Considered in this way, the matter becomes a question as to the connection between the rate at which n and a change, the nature and amount of oxidizing binder present, and the characteristic effects of the pigments or gums present. This promises to present complicated problems, the study of which has not yet reached more than a very preliminary stage.

Possible Applications.—The tremendous part that oxidation plays in the life of a protective film, and the evident connection between the values for n and a and the progress of oxidation, immediately suggest cases in which the measurement of these values might be of practical interest.

To illustrate briefly how measurements of n and a may be of value in giving more complete data as to the effect of agencies which accelerate oxidation. Table IX summarizes a test under a mercury-arc lamp on films of ordinary kettle bodied linseed oil, and a single pigment paint.

Incidentally, it should be noted how graphically these figures demonstrate the added protection against the action of light obtained by the addition of pigment to a drying oil. It is also evident that by this method the relative advantages offered by different pigments in this respect, may be studied and very accurately determined.

Variations in the Form of the Stress-Strain Curve.—As this investigation has proceeded, there has been increasing evidence that by abnormal treatment with moisture and temperature variations, films can be made to deviate entirely from the normal stress-strain curve. This fact is worthy of note since it gives one more clue in tracing the possible deterioration of a film under specified conditions. At present there is no evidence that will definitely connect such deviations with any one mixture of a drying oil with certain pigments. This provides an interesting field for future work, and emphasizes the importance of studying the entire stress-strain curve, and not limiting observations to effects on ultimate elongation and tensile strength.

TABLE VIII.—EXPERIMENTS ILLUSTRATING POSSIBLE ELASTIC LIMIT.

Film.	Load, g. per sq. cm.	Elongation, per cent.	Set after ½ hr. Release, per cent.
Linseed Oil ($n=1$) (Elastic Limit apparently near point of rupture.)	250	5	Not measurable.
	500	10	" "
	1 000	20	" "
	1 500	30	Break.
Paint (Fresh Sample) ($n=1.4$)	1 000	5	Not measurable.
	1 500	7.5	" "
	2 000	12.5	0.75
	3 000	35.0	4.0
	7 000	58	Break.
Varnish (C. W. Oil) ($n=2.1$)	10 000	5	Not measurable.
	40 000	15	" "
	50 000	25	0.5
	75 000	80	2.5[a]

[a] Still 2.5 per cent after 24 hr.

Ultimate Elongation and Tensile Strength.—The amount of distortion to which a film will submit before rupturing entirely appears to be a characteristic property depending on the components of the film and the stage of oxidation, or deterioration, and, therefore, cannot be considered to any extent apart from specific tests. Films of common paints and varnishes generally lose in ultimate elongation, and gain in tensile strength, as normal oxidation proceeds. But notable exceptions to this have been observed in the case of better grade varnishes, which will often hold a very constant ultimate elongation throughout a long period of oxidation, during which time the tensile strength increases steadily.

APPLICATION OF THE METHOD.

For several years there has been more or less sporadic seeking after an accelerated test which will enable the paint and varnish manufacturer to estimate properly the value of a new product in terms of years of actual exposure, without awaiting the slow process of exposure tests. The possible success of such ventures depends absolutely on a complete study and knowledge of the properties of the film, and their modification under the influence of the weathering agents, that is, moisture, temperature variations, and light, The work outlined in the preceding pages furnishes every evidence that with the development of methods for tracing the modifications in the stress-strain properties under specified conditions, the ultimate attainment of a dependable accelerated test becomes more probable.

TABLE IX.—EFFECT OF EXPOSURE TO ULTRA-VIOLET LIGHT.

Exposure at 8 in. under Cooper Hewitt Standard Laboratory Outfit. Temperature of film below 35° C.

Film.	Treatment.	Elongation, per cent.	Tensile Strength, g. per sq. cm.	*n*	*a*
Linseed Oil	Unexposed	40	1 780	1.+	0.021
	Exposed 3 hr.	31	2 600	1.3	0.001 18
	" 10 "	26	2 800	1.9	0.000 002 9
	" 13 "[1]	23	3 200	2.7	0.000 000 007 5
Paint	Unexposed	21.5	30 000	1.5	0.000 004 2
	Exposed 3 hr.	15	31 000	1.5+	0.000 002 8
	" 13 "	12	34 000	1.8	0.000 000 089

[1] A microphotograph of one of these specimens is shown in Fig. 12 (*b*).

The application of this test will undoubtedly uncover many advantages and defects in paint and varnish products that are apparent through past experience. One notable example is that of the final tenacity indicated by the stress-strain curves of the better grade exterior varnishes. The varnish manufacturer may well study this matter with the object of extending the outward bend of the curve even further along the line of the rubber stress-strain curve. The manufacturer of baking enamels should also be greatly interested in the application of this test, for in no other way can the proper temperatures and times for baking be so accurately determined. The position, form, and length of the stress-strain curve will tell beyond a question of doubt when heat begins to destroy the "life" of a film.

To what extent this method of handling films can be applied in routine control work, the author is not prepared to say. Perhaps the varnish manufacturer could best afford to adopt some such means for checking the physical properties of his product against the standard under predetermined conditions. Undoubtedly, the knowledge that these measurements can be made rapidly and with a fair degree of accuracy, when properly controlled, will lead to many applications in other fields where the physical properties of oxidizing films are of importance.

CONCLUSIONS.

Lack of space has permitted the inclusion of only such of the data at hand as seemed most fundamental, and which it was thought would prove suggestive to those desiring to utilize this method in carrying out less general investigations on certain products. From the beginning the author had felt that if any information of fundamental value was to be derived from the study of the stress-strain properties of oxidizing oils, and films containing oxidizing oils, it must come through a detailed study of the form of the stress-strain curve. Hence, emphasis has been placed on this phase of the subject. This does not argue, however, that an attack of the subject from other angles will not yield equally valuable results.

In concluding, the author wishes to express his appreciation for the many helpful criticisms and suggestions received from other members of our Research Department.

DISCUSSION.

THE CHAIRMAN (MR. H. A. GARDNER).—The paper by Mr. Nelson is a very interesting one, and I think he has been the first man to work out stress-strain curves for paint and varnish films, although we started over fourteen years ago at Grays Ferry to determine the stress strains of paint films, with a very interesting apparatus (Perry Filmometer). I think it quite proper to apply the methods of testing rubber to testing paint, because, after all, they are very similar in their structure from a colloidal standpoint. **The Chairman.**

MR. J. S. MACGREGOR.—I have been greatly interested in the curves, because I wonder if they mean anything about the life of paint. The baked varnishes or baked paints, as you all know, wear very much better than a paint that is air dried, and it has always seemed to me that the question at issue is not so much the tensile strength as the plastic flow. My experience has shown that a paint that preserves its plastic state longest is the one that is going to give us the maximum results. I do not mean for a period of two, three or four years, but for, say, twelve years, at the end of which time we have to repaint. My belief is that paint perishes as the result of stresses due to shrinkage within the film itself. During the formation of a gell, we always get shrinkage. I believe Professors Sabin and Thompson have determined the increase in gravity of a paint film that has been exposed for a given period of time—I have forgotten the exact figures, but they indicate loss in volume or shrinkage. The stress developed by this shrinkage is great enough to break any film and the question of tensile strength is not so important as mobility under stress. We do not want such great tensile strength that when a rupture does come it will break as glass will break. Glass has a very great tensile strength but slight mobility and if you put a stress on it there will be no flow or stretch, whereas rubber, on the other extreme, will adapt itself to the stress placed upon it, and I think that the ability of a paint film to flow like the rubber would be desirable and this is the factor we must study. If we get the plastic flow of a solid film, together with the stress strain curves, it may tell us a great deal. I am not sure that we are interested in the hardness of a film as an indication of its ability to last on outside to exposure. **Mr. MacGregor.**

MR. G. W. THOMPSON.—I have just one word to say with regard to this paper; it represents an immense amount of work which it is **Mr. Thompson.**

Mr. Thompson. to be hoped will result in profitable and practical results, but I have this suggestion to make: that if the work which is being undertaken, which is colossal in character, is going to yield practical results, it will not be through an attempt to break down a paint film by oxidation, and then see what the changes are, due to oxidation. I am confident that paint films are not destroyed, relatively speaking, to any material extent by oxidation. We can paint any ordinary white paint, and protect it from moisture and it will practically last forever; oxidation will go on indefinitely, but the paint will not decay. The destructive influence upon paint exposed to the weather is the alternate moistening and drying. Linseed oil will take up water and give it back, but every time it does that it is undergoing a change which is destructive in its character, and I am confident that if these tests are to be of the practical value I hope they will be, that they will have to be changed to the extent that comparison shall be made between paints which are alternately subjected to moist conditions and dry conditions. A paint subjected to conditions of definite degrees of humidity will last a very long time. It is the alternate change from dry to moist conditions that produces most of the destruction of paint films.

Mr. Nelson. Mr. H. A. Nelson.—Mr. MacGregor's suggestion that we are not interested in the tensile strength, is essentially true in so far as the resistance to the forces of expansion would be negligible. But the combination of physical properties indicated by the form and position of the stress-strain curve certainly has a deeper significance, and justifies a careful study of the entire curve. I doubt if we can measure directly what Mr. MacGregor calls the "plastic flow" of a film, except as it might be indicated by the "permanent set." My attempts to apply Dr. Nutting's formula for what he refers to as "Plastic-Elastic flow," were not very successful, although there are indications that oxidized films exhibit properties which might be so described. This matter will be the subject for further investigation, but at present it seems that a study of the stress-strain curves as outlined in the above report, has the essential advantages of simplicity and a mathematical form to serve as a working basis.

As to Mr. Thompson's suggestions, he will no doubt learn, as soon as he has an opportunity to read the original paper, what I have not made clear in the time allowed for this presentation, *i. e.*, that the work so far written up is intended to cover only such matter as is fundamental to this method for studying the physical properties of oxidizing films. It is with this knowledge in hand that we are to follow the destructive influences on oxidizing films, which are commonly ascribed to variations in moisture content, temperature and light.

MR. F. P. VEITCH.—I would like to emphasize further the importance of perfect control of the temperature and humidity conditions during the time of the preparation and the testing of the film. We know that both humidity and temperature have a great effect on testing results. They have a greater effect on some materials than others. I do not know how it will be here, but in the testing of paper and some other materials, if there are fluctuations in humidity or in temperature during the time of test, the results may be decidedly misleading. There are instances where the effect is not great. If this is one of them it is a small matter. If it is a case where they are great, it is a very important matter. It is essential, I think in such a case, to have practically perfect control, that is, the same conditions, during the whole time of the test. During the preparation of the material for test and during the time that the test itself is being made, changes may take place in a moment that with sensitive materials will make the results valueless. **Mr. Veitch.**

MR. F. C. BREYER.—I think it is perhaps important to the members to realize the relationship of this particular piece of work to the rest of the work we are doing on the question of accelerated aging of paint films. We have four principal steps of attack. The first is the quick laboratory disruption of a paint film or paint daub on a glass palette, and a study of the chemical products of decomposition. The next step Mr. Nelson has told you of, and I can say that his work is just started. You could ask a hundred questions as to how we could apply his findings. What we have learned is simply how to make the tests. The third step is to take the same films that we have artificially aged alone and age them when adhered to various surfaces. The fourth step is to take that same paint which has been tested in the three previous accelerated agings and put it on a house where you get some other conditions you have not previously calibrated. These are four distinct steps and they must be carried on in parallel, until the relationship between them is fully understood. **Mr. Breyer.**

I think there are two very important things that this paper brings out that are worthy of very serious consideration. One of them is that it shows very clearly that moisture and ultra-violet light, without any doubt are the major influence of destruction. Just what the *modus operandi* is, whether these agents accelerate the oxidation or not, we have not found out. Temperature expansions and contractions reveal the loss of the elasticity. The destruction of the linseed oil shows that the great protective agency, the oil, is destroyed by ultra-violet light and that probably the prime function of the pigment is to protect the oil from this light. The next thing the paper brings out is that it

Mr. Breyer. enables those of us interested in the testing of not merely paint films but all materials which are subject to mechanical stress, to understand these materials somewhat better; it gives us some idea of the structure of those materials that lie on the border line between liquid and solids and enables us to better picture what happens when the specimens are put in the tensile testing machine. Now that is of importance to the whole Society because it applies equally to metal as well as it does to paint and rubber testing, and an understanding of what takes place; the fundamental reasons for the behavior of a paint film and a rubber film and a metal film is far from being clear. Such work as Mr. Nelson's is needed before we can advance much further in either practice or understanding.

THE USE OF SECONDARY REFERENCE STANDARDS IN PROCESS PROBLEMS OF COLOR MEASUREMENT.

By H. S. Busby.

Introduction.

It is proposed to make this discussion one of a series covering the fundamental and practical problems involved in setting up an effective textile color laboratory, for routine color testing of the materia of regular process problems.

Speed in matching being a prime requisite, another section of this general problem must be devoted to an investigation that, it is hoped, will lead to an infinitely more rapid, and at the same time, uniformly constant, method of measuring and charting colors by means of the approximation of a "match point," so that they may be referred to the methods of ultimate color specification in use among physicists at present. That such a system would render great assistance to process workers of all sorts is axiomatic.

This paper has to do with a consideration following immediately upon that of speed in matching: it is, in fact, a corollary to it.

I. The General Laboratory Situation in Regard to Means of Color Analysis.

At present, we have as the most common means of matching and specifying colors, intensities, etc., such instruments as the spectrophotometer, various styles of flicker-photometers, the colorimeter of Pfund,[1] colorimeters based upon the selective absorption of parts of the spectrum, by means of filters and wedges, the optical bench, comparison-field photometers, densitometers, and the sectored-disk machine.

The history of the evolution of colorimetry is a record of the attempt to meet with suitable instruments the need for accurate color specification. In view of the fact that process work, which depended mainly for its refinement upon color, was first studied in detail in western Europe, and later followed the development of aniline dyes in the Central European countries, it was natural that the corresponding instrument development should have also occurred in those countries. Under these conditions special types of instruments were developed for the work at hand, and some very fine types have resulted. They are, in fact, the chief elements of color equipment we use today.

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[1] A. H. Pfund, "A New Colorimeter for White Pigments," *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part II, p. 441 (1920).

But, because of this very specialization is the colorimetric instrument situation we have today; it is practically necessary to make a very extensive investment in a selected list of these "special instruments" in order to carry out the analysis work[1] demanded under the spur of competitive process work, if a laboratory is to serve its organization to the end that the organization keep abreast of the present technical pace.

It may be said, in general, that the degree of accuracy in the ability to measure color differences depends upon the sharpness of the comparison condition, the rapidity of adjustment of match, the proximity between sample and reference standard, and the nature of the comparison field and its surroundings. While the instruments provided for such analysis are excellent, those which furnish the best basic comparison (like the Kœnig-Marten Spectrophotometer) are so slow in operation as to be impracticable in routine matching of great numbers of samples. Then, too, the data furnished through an analysis on such machines are unintelligible to any but the expert, and are particularly unsuitable for round-table discussion of manufacturing color problems.[2]

Hence this slower type of color analysis is necessarily restricted to the more basic problems of *ultimate* color specification, while there is a constant increase in development of more specialized types of equipment, to solve the every day problems of *rapid* color specification demanded by particular fields of industry. In this category is the colorimeter of Pfund,[3] a good typical example of the adaptation of an instrument—a novel application of a fundamemntal principal of physics—to the solution of process problems. Though an industry that has seen marvelous commercial expansion, the textile world has only sensed the borderland of this idea, if we consider the possibilities for development that lie open to that industry.

The idea of using, in research, any units of measurement but those couched in terms of physical constants is naturally the antithesis of the academic viewpoint. Moreover, that there is much to be gained from an earnest study and correlation of the efforts of the academists, is evident from recent studies of great merit and of marked assistance to the worker in the process field.[1] [2]

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[1] E. B. Leary, "A New Device to Measure Color Shades," p. 15, *American Dyestuff Reporter*' March 14, 1921.

[2] F. E. Ives, *Journal* of the Franklin Institute, December, 1915.

[3] A. H. Pfund, "A New Colorimeter for White Pigments," *Proceedings*, Am. Soc. Test. Mats., Vol. XX, Part II, p. 441 (1920).

It is proposed to study the effect of using for everyday problems of matching and recording color, in place of the instruments referred to above, an instrument whose calibration will be, not in wave lengths of light, but in areas of colored media, which media may be adapted to the nature of the work in hand. Indeed, so far has this factor of adaptation been carried that where difficulties arose, due to differences between the nature of the surface of the sample and the *standard* surface, standard surfaces were prepared that conformed, in all respects, to the required conditions, being provided, in the case in point, with a degree of sheen approximating that of the average of the surfaces being matched.

The use of such "secondary standards" (to use the term in contrast to the "primary standards" of wave length, diffuse reflection, brightness, etc.) is more than justified by results when we are able to prepare suitable standards that give us a method of matching that is:

Much more rapid than any obtained with instruments of direct absolute physical-constant reference;

Of determinable accuracy;

Referable in its standards to the same fundamental constants of measurement as the slower absolute instrument;

Based on standards that are repeatable and replaceable with a high degree of precision.

Permanent, as regards fading, surface mar, chemical alteration of structure, and corrosion of the standard surfaces.

It must be understood, throughout, that this method is not meant to be a substitute for, nor competitor of, the fundamental instruments referred to above.

II. A PROPOSED SOLUTION OF THE PROBLEM.

The sectored-disk method of matching colors is so well known as to require no further elucidation. Studied at length by Maxwell[3] and others; methods of charting colors from such analysis were developed by Maxwell,[4] Rood,[5] Munsell,[6] Howland,[7] and others, and instruments for this purpose were developed by deAbney, Howland, Munsell, and others. Although each of these instruments contributed a forward step to the art, none of them were sufficiently complete in development to cover the ground in all the phases that were necessary for general usefulness and each of them possessed one or more (in some cases all) of the faults listed below:

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[1] L. A. Jones, "The Fundamental Scale of Pure Hue and Retinal Sensibility to Hue Differences", p. 63, *Journal* of the Optical Society, March-May, 1917.

[2] I. G. Priest, "Preliminary Notes on the Relation Between the Quality of Color and the Spectral Distribution of Light in the Stimulus." p. 388, *Journal* of the Optical Society, September, 1920.

[3] "The Collected Papers of James Clerk Maxwell," Vols. I and II.

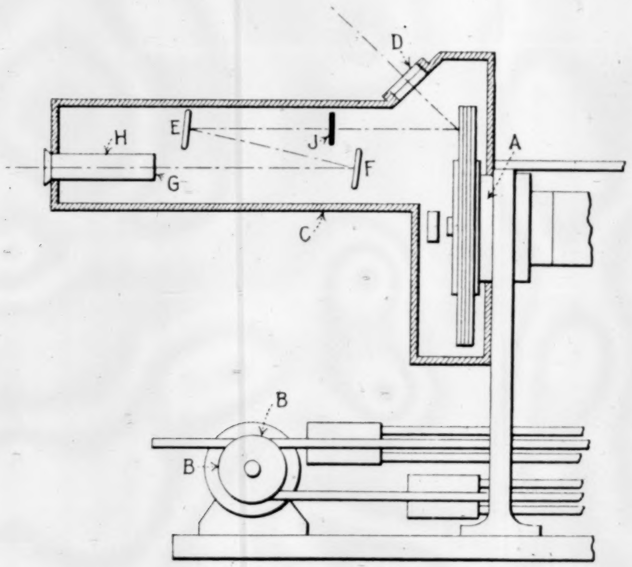
[4] *Ibid.*, Vol. II.

[5] O. N. Rood, "Students Text Book of Color, or Modern Chromatics," p. 228..

[6] A. H. Munsell, "A Color Notation."

[7] A. Howland, "A Comparative Color Photometer," p. 29, *Science Conspectus*, Vol. VI, No. 2, 1916.

1. Loss of time due to necessity of stopping the machine for each adjustment of the sector.



A – Adjustable Sectors.
B,B′– Sector Controls.
C – Inclosure.
D – Light Aperture.
E,F– Mirrors.
G – Collecting Prism.
H – Observation Tube.
J – Diaphragm (Iris)

FIG. 1.—Diagram of Color Matching Machine.

2. Decrease in color-sensitivity and color-memory factors of the eye with such frequent stops and starts.

3. Lack of adaptability to the handling "adjacently" of all sorts of sizes and shapes of samples.

4. Inability of adjustment, of not only *relative areas* of each color-element to each other color-element, but individual area change of each color-element, independently of the ~~other ele~~ments.

The machine designed to overcome the difficulties that had been met previously took account of the fact that had been noted by previous workers that a concentrically located, smaller set of disks is often convenient for purposes of comparison with the principal adjustable disks. This has always been a particularly valuable feature in matching patches of pigment colors. Hence, provision was made, in the construction of the set-up, for the insertion of auxiliary sectors, samples, light-sources, adjusting devices, various auxiliary mechanical aids to matching, etc., and the whole so arranged that the matching-field always satisfied the conditions of a proper photometric field, arranging also, by means of a collecting prism and eye-piece, for the observation, adjacently, of the color fields under comparison.

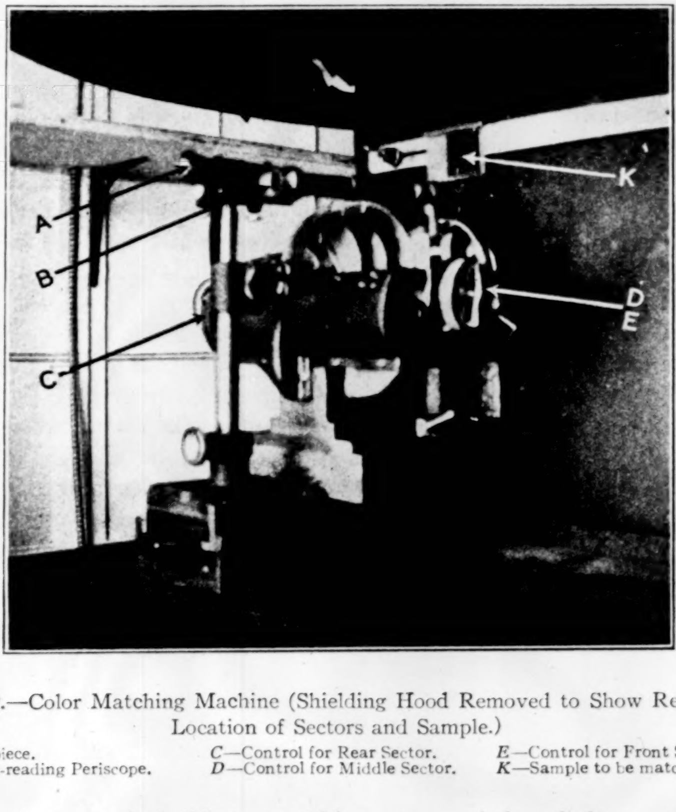


FIG. 2.—Color Matching Machine (Shielding Hood Removed to Show Relative Location of Sectors and Sample.)

A—Eyepiece.
B—Scale-reading Periscope.
C—Control for Rear Sector.
D—Control for Middle Sector.
E—Control for Front Sector.
K—Sample to be matched.

Fig. 1 is an optical diagram of the arrangement of the matching machine and its surrounding fittings.

In the completed machine we achieve:

1. Adjustability, relative to each other (while the machine stands still or rotates) of *three* colored, or *two* colored and *one white* sectors.
2. Variation (while the machine stands or rotates) of the area of any colored or white sector.
3. The observer's eye remains at one fixed location throughout all the process of matching.
4. The measurement of the color in terms of sector area may be read off while the machine continues to rotate, or after it stops, each change in sector area-setting being permanent until actuated by the sector-controls.
5. An approximate match to the desired color is determined by a predetermined method, whereupon the sectors are adjusted "above" and "below" the "match point" (see Introduction) until a match is obtained, and it is recorded in terms of the sector-areas that constitute it. This method of adjustment coresponds to the "method of swings" used in weighing with an ordinary laboratory balance.
6. Check measurements agree within changes in sector area equivalent to 0.1 per cent. of the total sector circle.

An undertaking of the sort embodied in underwriting the construction of this machine calls for the highest type of commercial vision and acumen. The machine has a field of usefulness in everyday routine work, but its chief contribution is that it will handle, quickly and effectively, the enormous quantity of colored samples that must be studied in order to determine an authentic basis for conclusions affecting the laws of color in process. The chief value of the method of rapid matching that is being investigated lies, then, in the quantity of the data that can be studied by it in a given space of time.

The machine alone would seem to be simply one more of the "specially constructed" class of instruments referred to above, but if cognizance is taken of the fact that the investigations made on it are forming the ground-work of a more comprehensive system of rapid color analysis it will be seen that the academic goal of the machine is simply that of an auxiliary to the general problem of research on interchangeable color notation, and as such would tend to *decrease* rather than to *increase* the total number of types of machines for color matching in the future.

A large part of the effort in color research, at the present stage of its development might, indeed, be devoted very profitably to the development of a colorimeter that would handle more phases of matching than does any now in existence. And the chief contribution to this end would be agreed upon factors of interchangeability and transposition in notation.

III. APPLICATIONS.

Illustrative of the application of the method several sets of samples are shown giving the differences of a number of colors, in terms of the three generally accepted factors of color measurement, and the nearness of agreement, in terms of both notation and plot, of colors that are nearly matches. These illustrations shown the adaptability of this method of measurement to such work as color charting, grading, etc., and the building up of specific colors into scales of graded color[1] and harmonious relation.[2] [3] Fig. 3 is a chart showing the loca-

ANALYSIS (Howland Notation)

Color	Hue, percent	Strength	Luminosity
X	R – 88.9 B – 11.1	59.6	16.74
Y	R – 89.0 B – 11.0	65.91	18.61
Z	R – 89.0 B – 11.0	69.2	19.47
V	R – 72.5 B – 27.5	25.5	10.65
W	R – 72.6 B – 27.4	27.91	11.62

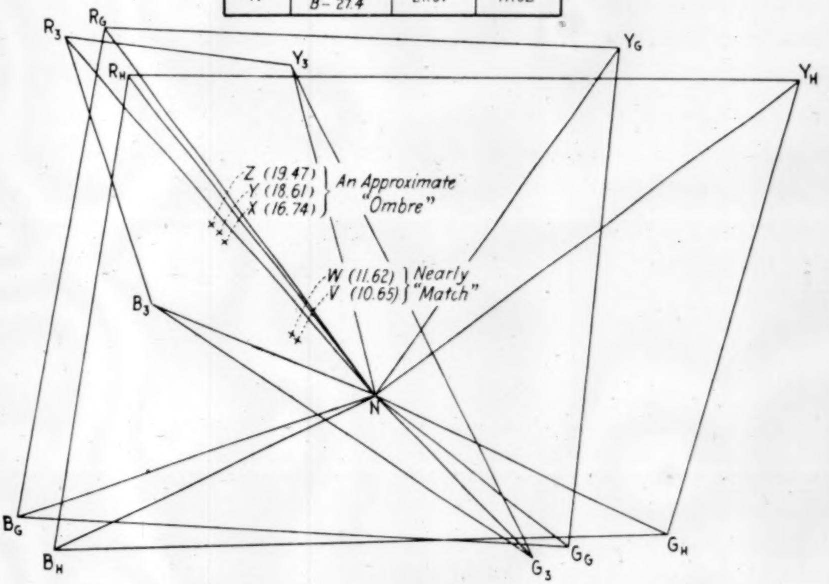


FIG. 3.—Chart Showing Location of Three Sets of Standard Colors

tion of *three* sets of standard colors used in matching. These are plotted in the relation which they bear to each other. Those labeled R_H, Y_H, G_H, B_H, are the four standards used by Mr. Arthur Howland in his analysis work.[1] Those labeled R_3, Y_3, G_3, B_3, are four sets of sectors covered with silk, those labeled R_G, Y_G, G_G, B_G, are colors specially prepared to approximate the conditions of the surfaces being matched.

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[1] L. A. Jones, "The Fundamental Scale of Pure Hue and Retinal Sensibility to Hue Differences," p. 63, *Journal* of the Optical Society, March-May, 1917.

[2] Wilhelm Von Bezold, "The Theory of Color," p. 100.

[3] M. E. Chevreul, "The Principles of Harmony and Contrast of Colors," Part II.

If the colors X, Y, Z, etc., are analyzed in terms of any one of the sets of standards, then their location on this composite plot gives also their analysis in terms of any other set of standards on the plot; hence, their analyses, in terms of these, can be read off interchangeably by the method of charting-relation described by Maxwell[2] and Howland.[1] The notation used is that of Howland (for convenience in comparing same to his colored sectors), although the matching was done with another set.

It will be noted that the appearance of the samples corresponds with their position on the chart, that is, the samples more red in appearance are nearer R than those that are more blue in appearance. Colors occupying approximately the same positions are near matches, those widely separated differ in some quality of their color.

The average time required for matches of the sort shown by the chart is from three to eight minutes, as against a minimum of twenty minutes by former sector machines, and a considerably greater amount of time for analysis on such machines as a spectrophotometer.

Acknowledgment.—I am indebted to Mr. Arthur Howland for assistance in making the measurements contained in this paper, also to the late Prof. A. H. Munsell for expert counsel as to the relations existing between the different systems of color notation. Assistance of a very timely character in the selection and preparation of the proper coatings for the sectors of the machine, was given by Mr. F. P. Ingalls to whose sympathetic advice and suggestion we owe much of the credit for the successful outcome of the type of standards finally chosen.

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[1] A. Howland, "A Comparative Color Photometer," p. 29, *Science Conspectus*, Vol. VI, No. 2, 1916.

[2] "The Collected Papers of James Clerk Maxwell," Vols. I and II.

DISCUSSION.

Mr. Ingalls.

MR. F. P. INGALLS.—You have already heard what Mr. Busby has had to say with regard to the application of this particular instrument that he had devised to the paint problem. This instrument may also be applied directly to almost all industries in which color measurement is a matter of fundamental importance. In the paint industry in particular our methods, as you all know, have heretofore been to get a standard sample, arbitrary in its nature, and then put the newly manufactured batch or some other manufactured paint, up against it and see if it matches. This question of matching involves some other things besides mere color, but we have never been able, in any way that could be applied in the ordinary paint laboratory, to get anything like a definite measurement or anything that you could figure on or calculate by or set down on a piece of paper as something reasonably permanent. Mr. Busby has solved one of the most important problems that we have ever had, because color in our work is unquestionably of paramount importance.

This machine does a number of things that no other instrument has ever done, and the importance of it is scarcely to be exaggerated, even though at the present time it may be regarded as not wholly complete. In matching a paint, we have other things besides color, as I remarked, and those of you who are interested daily in paint problems understand quite well the request that somebody shall have a paint of one type and have them send in a sample of a paint of another type, with the remark that this sample is for color only. We are requested to match an oil color in a superfine color, or a color in Japan, whose real color will appear only after it has been covered with a coat of varnish, and then when you do the best you can under the circumstances, you will find that the complaint comes back "You have not made an exact match." Now an exact match is entirely impossible under the conditions.

Now the importance of being able to measure these differences appears in another way: we also have complaints of paints fading, paints that are made from earth pigments that cannot, by any possibility, fade as far as any change in their effect on the reflected light, but when mixed with a vehicle and the refractive index of that vehicle changes by exposure, oxidation, or decay, you have a different appearing surface that is of the highest importance. One of my most recent

Mr. Ingalls. complaints is of a gray. The pigment was a perfectly stable pigment, a lampblack tint, and everybody knows that lampblack does not fade. But this gray had faded out very much; it started with a dark gray and faded out to a light gray. What was the explanation? The explanation was that after a severe exposure, the oil, or the oil vehicle, had been subject more or less to decay and you had practically the same condition of affairs that would apply to a piece of wet gray cloth dried out in a spot, the dried out spot would be lighter than the place that stayed wet, not because of any change in the cloth or the color of the cloth, but because of the wide difference between water and air in their refractive effects.

Mr. Busby's machine can be developed to a point where we can not only detect differences in actual color but in the surface character. Almost everybody who has had this problem of matching color, particularly during the war, will know that olive drab was supposed to be a color of pretty definite nature and it was selected on account of its low visibility, we will say. But who on earth was ever able to get two samples of olive drab that matched? No two had the same color. Nobody knew what the standard of olive drab was, and if you looked at a company of soldiers going down the street, you could see as many shades of color almost as there were men. Why? Because there was no standard, it was simply something in the neighborhood, and after they did get a painted sample and decided that this was the sample they wanted, you could not keep it there.

Your color cards do not match: of course they do not. They did when they were first put on, but three months later they do not. Even at that they are one of the best ways we have had so far of giving some idea of the shade of the paint we had to sell. This machine is going to enable us to nail that thing down on all four corners, and we hope before we get through that the U. S. Government, when it wants olive drab, can telegraph to Chicago a description and then when it arrives at its destination it will be of the proper shade.

That seems like a dream, but it is a dream that this instrument places practically within our reach, and I believe that before another two years, and hope that before another one year, that we will be so near it that it will be practically an accomplished fact. Another thing, this is referable to a standard physical measurement; we do not have to have some indeterminate arbitrary standard; we can establish a standard of mathematical value. I say that the importance of this machine, eliminating as it does the weaknesses that existed in practically every other instrument of its kind before, is one of the things that we can not well over-rate in importance.

Mr. Pfund.

MR. A. H. PFUND.—I have but very little comment to make on Mr. Busby's paper. By using Maxwell's well-known color disk, he is able to match colors to a high degree of precision, and I can only compliment him on the success of his labors in this difficult field. Since, however, this Society has taken the subject of colorimetry seriously, I cannot help emphasizing once more, at the risk of appearing academic, the necessity for getting down to real fundamentals. The virtue of this color machine, quite apart from its accuracy of readings, is supposed to be its reproducability. Now these sectors are painted, some with red paints, some with yellow, some with green, some with blue paints, etc., and we all know that the surface of the red paint does not reflect red light only, it reflects blue and green light, but more red than of any of the other colors, therefore it becomes necessary to specify the colors of these sectors by means of some ultimate instrument. Now the fundamental method of colorimetry I think is generally agreed upon to be the monochromatic system of colorimetry. This method is not new; it was developed by Hemholz and others many years ago. According to this method it is possible to match any color by taking a certain amount of white plus a certain amount of monochromatic light and, by knowing the amount of white light and the amount of colored light and the wave length of the colored light, you can specify that color absolutely; the number of fundamental units you have to use is reduced to a minimum. It is possible to construct an instrument in which these three quantities are obtained not only correctly but rapidly. Within a few minutes after you have obtained your readings, it is possible to put down in black and white the *brightness, saturation* and *dominant hue*. This gives you those three quantities in which you are interested. I have no quarrel with secondary instruments to be used in factory practice any more than I have with anyone who attempts to determine the temperature of water by dipping a baby in it; if the baby gets blue, you know the water is too cold and if it gets red, you know the water is too hot, but you have got to calibrate your baby. This monochromatic system of colorimetry has a sound physical basis; it is being championed by the Optical Society of America and by the Bureau of Standards. It therefore seems desirable to me, that this matter be investigated more fully before any decisive steps are taken.

Mr. Thompson.

MR. G. W. THOMPSON.—The work which Mr. Busby has done gives us a certain definite practical improvement in colorimetry. Of course, Mr. Busby alone is familiar with his own machine, as I presume not more than one has been built, and the rest of us can simply speak with regard to the instruments with which we are familiar

Mr. Thompson. and of which Mr. Busby's machine is a development. Boiled down, the advance which Mr. Busby has made in his machine is simply in being able to adjust the sectors during motion so that any proportion of any particular hue, etc., can be introduced at will, which enables the operator to get very quick and numerous results. My experience has been entirely with the Howland machine which, as Mr. Busby has truly said, is a slow machine to operate, and I presume with his machine he can make probably ten times as many tests in a given length of time as can be made with the Howland machine. We have in our laboratory a machine which operates somewhat on the same principle as Mr. Busby's machine, which was designed solely for the purpose of measuring tinting power or tinting strength, and which consists of a disk of steel, opposite quarters of which are painted with a black paint and the other two quarters are painted with a nearly white or light gray paint, and to cover the portion which is black, there are double sectors which are also light gray. The double sectors are on a separate shaft which runs inside of the main shaft driving the complete disk and changes its position by an internal screw, and by pressure operated from the back so that by forcing the inner shaft out, the sectors change their position with reference to the black. Now by this machine, with a proper optical instrument, you can compare a white lead rubbed up with the standard amount of black and match it very closely, and by simple tests which we have run, we can match any gray we can produce in rubbing up white lead and therefore determine whether the tinting strength is 110, 120 or 95. We do not attempt to get closer than 5 per cent in those readings, but it works on the same general principle, I presume, as Mr. Busby's machine.

The question of color matching presents two phases which are equally important, and if we neglect either of these phases, we are going to get into trouble. Mr. Ingalls has already referred to the lack of care in matching. That is one phase. In my opinion, there is another phase which is the opposite, the attempt to over-match. Perhaps I should not emphasize the attempt to carry matching too far, but if a purchaser of paint is going to carry his matching too far, even with Mr. Busby's machine or any other matching machine, he is going to fall down and is going to have grounds for complaint, because even after paints are matched they change somewhat in their color, and it seems to me that what we should try to do is to arrive at certain more or less definite limits. Say we adopt Mr. Busby's machine as finally developed, we should then have tolerances perhaps of 1 per cent or whatever it may be, with reference to each color. I am very strongly of the opinion, in spite of what Mr. Ingalls has said, that in a great many cases there is overmatching today. Now I can give you lots of cases of undermatching. I remember, for instance, that Professor Ladd, in North Dakota, sent out color cards for colonial yellow and colonial gray, and after these paints were applied to his test fence, I think it was the 1907 fence, there were not two grays alike, or two yellows alike, and yet they were all matched by the same color card. That is undermatching. **Mr. Thompson.**

Now in regard to what Mr. Pfund has said, I would like to take time, but I am not going to do so, to show you that the fundamental study of color is a very important thing for Committee D-1 and this Society. Mr. Pfund has referred to the monochromatic color machine system. I am confident that the system Mr. Busby has referred to can be converted with proper factors into a monochromatic system. As a matter of fact, every color, as Mr. Pfund has said, can be resolved into two components, the white light and a single chromatic color; but we obtain our single chromatic colors by blending; we may obtain our single chromatic colors by the blending of two or more other single chromatic colors. If we spin on Mr. Busby's machine or a Howland machine a red and a yellow, we will get an orange. We may say that that orange is composed of the red and the yellow. I think the more accurate method of expression would be that the orange obtained is a resultant of the red and yellow and so far as the eye goes, it is orange and it is not red or yellow.

There is one very great difficulty connected with this subject, and if Mr. Pfund will get the students, professors and teachers about color and optics to agree in their nomenclature, he will have probably done a great deal of good work on this subject, because I have attempted to find, in all of the books published, some uniformity in terms, and they do not agree at all. Sometimes they talk from the viewpoint of the artist; sometimes they talk from the viewpoint of objective color, and at other times from the viewpoint of the subjective color, and there is very little uniformity, and no clear thinking. As I said, I would like to go into the fundamentals of color, but I have already taken up too much time. I believe that Mr. Busby has indeed advanced this subject, and I hope we will all be able, in some way, to profit by it by obtaining the details of his machine, and so perhaps we can experiment with them, and if we can hope to do so, even improve upon his machine.

Mr. Busby. MR. H. S. BUSBY.—I am, perhaps, unfamiliar with this subject as discussed from the point of view of the technical paint man, but never have I heard these practical color problems presented more concisely.

Mr. Busby.

This point that has been touched upon, (*viz.*, standardization in the nomenclature of color) has been undertaken very definitely by the Optical Society of America, so that I think you can say that problem is assured of solution. The line of effort to be made, and the goal to be reached are definitely known.

Regarding this question of "overmatching" or "undermatching:" this is one of the most important features of the industrial application of color work, because in trying to establish color reference and harmony scales it is necessary, even in ordinary matching, to make use of so many standards (*i. e.*, to make a complete color chart) that it is very difficult to determine where to establish the divisions. We have undertaken this work with the view of trying to establish the law that governs the recurrence of cycles of colors, for we know that essentially the same color recurs continually (but each time in slightly different admixture with various shadings or tonings, each one just slightly different from the others)—so that it will be necessary to definitely establish a color in terms of exact match, and determine the allowable variation from this match, based on the nature of the problem in which the color is to be used.

Concerning further work that is to be done with this machine, I will say that it is our intention to do all in our power to assist the work of the Society by bringing before it certain solutions of practical color problems which are now in process of determination and for which the machine will be the means of specification.

Mr. Breyer.

MR. F. G. BREYER.—Monochromatic *versus* trichromatic colorimetry is probably one of those questions that we are always going to have with us. I am only a shoemaker at colorimetry and I must confess that the trichromatic colorimetry has confused me on a good many occasions, but as soon as I acquired, not a thorough mastery, but at least a thorough understanding of monochromatic colorimetry, I could think and reason in terms of it, which I could not do in terms of tricolorimetry measurements.

The Chairman.

THE CHAIRMAN (MR. H. A. GARDNER).—I think that subject will be considered this year by the Sub-Committee, of Committee D-1, on Physical Properties of Paint Materials, of which Mr. Ingalls is chairman. Before passing to the next subject I think it might be well to recall what these meetings were a few years ago. Up to the last two or three years, the presentation of a paper was generally followed by acrimonious discussion. The work we did in those years was not very constructive; we carried on exposure tests of paint on test fences and had heated discussions as to whether we should add so much lead or so much zinc to the paint. We thought almost entirely along chemi-

The Chairman. cal lines. During the last two years we have worked along physical lines. Every paper presented during the last three years has had to do with the physical properties of paints and paint pigments. I think it was Mr. Breyer who first pointed out the advisability of thinking along the physical need of the problem. At the present time we are specifying varnishes entirely on physical tests and giving but little attention to their chemical makeup. This is due to the fact that we can tell very much better from the physical properties what a varnish will do in practice. It is possible that sometime in the future we will be able to do the same thing in paints.

ON PLASTIC FLOW THROUGH CAPILLARY TUBES.

BY E. BUCKINGHAM.

For interpreting their observations on plastic flow, Messrs. Bingham and Green[1] have adopted the assumption that the rate of shear in a given plastic material is proportional to the excess of the shearing stress F over a certain constant yield value f, below which the material behaves as a solid. If v is the speed at any point and y denotes distance perpendicular to v, the hypothesis is equivalent to assuming that in the equation

$$\frac{dv}{dy}=\mu(F-f) \qquad (F \geqq f) \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

the "mobility" μ and the "yield value" f are constants of the material, dv/dy) vanishing for $F<f$.

From this assumption, the authors have obtained an equation for flow through capillary tubes which enables them to find values of μ and f from their experimental data. But on account of a mathematical oversight, which amounts to ignoring the condition $F \geqq f$ to which Eq. 1 is subject, their equation is only a very rough approximation, and it does not fit the observations well. The correct equation which follows from Eq. 1 is given below.

Slow Steady Flow through a Long Round Tube.—We consider steady stream line flow under a pressure P, through a tube of length l and radius R, and we assume that the end and kinetic energy corrections are negligible. The longitudinal force, due to the pressure, on the material inside a cylindrical surface of radius r, coaxial with the tube, is $\pi r^2 P$ and the resulting shearing stress at radius r is $F=\pi r^2 P/2\pi rl =rP/2l$. Substituting in Eq. 1 and changing y to $-r$, because the speed *decreases* as r increases, we have

$$-\frac{dv}{dr}=\mu\left(\frac{Pr}{2l}-f\right) \qquad \left(\frac{Pr}{2l} \geqq f\right) \ldots\ldots\ldots\ldots (2)$$

For $Pr/2l < f$, there is no shear: hence the material inside the cylinder of radius $r_0=2\,lf/P$ moves as a solid plug. Between r and R, the material yields, and if v_R is the slip at the wall and v_r the speed at radius r, we have

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[1] *Proceedings*, Am. Soc. Test. Mats., Vols. XIX and XX, Part II (1919 and 1920).

$$v_r - v_R = -\mu \int_R^r \left(\frac{Pr}{2l} - f\right) dr = \mu\left[\frac{P}{4l}(R^2 - r^2) - f(R - r)\right] \ldots\ldots (3)$$

The speed of the solid plug, found by setting $r = r_0$ in Eq. 3, is given by

$$v_0 - v_R = \mu\left[\frac{PR^2}{4l} + \frac{lf^2}{P} - fR\right] \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Thus the speed distribution curve is not a complete parabola but has the vertex cut off.

The Volume Rate of Discharge.—This is, evidently, given by

$$\frac{V}{t} = \int_0^R 2\pi r dr \cdot v = \pi r_0^2 v_0 + 2\pi \int_{r_0}^R v_r r dr \ldots\ldots\ldots\ldots (5)$$

Upon inserting the values already obtained for r_0, v_0, and v_r, integrating, and setting $p = 2lf/R$ as a matter of definition, the result is

$$\frac{V}{t} = \frac{\pi R^4 \mu}{8l}\left(P - \frac{4}{3}p + \frac{p^4}{3P^3}\right) + \pi R^2 v_R \ldots\ldots\ldots\ldots (6)$$

in which the last term vanishes if there is no slip at the wall, and the first is to be omitted when $P < (2lf/R) = p$.

Introduction of Green's Hypothesis of Viscous Slip.—If there is a very thin lubricating layer of liquid, of thickness ϵ and fluidity ϕ, between the plastic material and the wall, we have for points in this layer $-dv/dr = \phi rP/2l$. Since the layer is very thin and adheres to both the wall and the plastic material, we have $-dv/dr = v_R/\epsilon$ and $r = R$, whence the slip is

$$v_R = \frac{\epsilon\phi RP}{2l} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

and the resulting form of Eq. 6 is

$$\frac{V}{t} = \frac{\pi R^4 \mu}{8l}\left(P - \frac{4}{3}p + \frac{p^4}{3P^3}\right) + \frac{\pi R^3 \epsilon\phi P}{2l} \ldots\ldots\ldots\ldots (8)$$

General Shape of the Discharge Curve: The curve represented by Eq. 8 when $\epsilon\phi$ is constant has the general shape shown by *OAB* in Fig. 1. The ordinates of *OACD* represent the part of V/t due to the viscous slip. From O to A this is the whole discharge, because for $P<p$ the material moves as a solid plug in a lubricated tube. At A, shearing begins, and the difference of ordinates of AD and AB represents the part of V/t due to plastic yield.

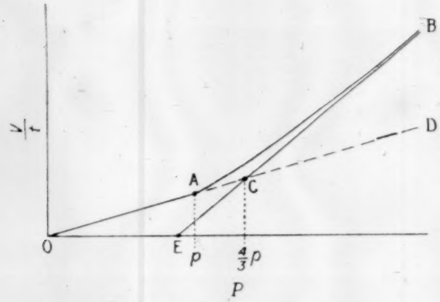

FIG. 1.

Qualitatively, OAB is very like Mr. Green's latest curves.[1] If $\epsilon\phi$ is not constant but increases with the speed, both the slip curve OD and the asymptote EB are concave upward and the resemblance is still closer.

To decide whether Eq. 8 is capable of representing the facts quantitatively would require the examination of more comprehensive data than have been published; and it cannot yet be regarded as at all certain that the assumptions embodied in Eqs. 1 and 7 are a sufficiently good representation of what actually occurs.

This paper will be published in more detail elsewhere.

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[1] *Loc. cit.*

DISCUSSION.

Mr. Herschel.

MR. W. H. HERSCHEL.—Mr. Buckingham's work, I think, is very trustworthy because it has been checked up mathematically entirely independently by Mr. C. A. Briggs, of the Bureau of Standards, and what remains to be done now is to determine the simplest way to apply these equations to laboratory tests. You will note in Fig. 1 that the intercept *OE* does not give you the value of p and therefore it is not evident just what is the simplest method to obtain the significance of your laboratory work. In the laboratory you plot flow against pressure and obtain a sort of a curve ending in a straight line, the most accurate part of the work being the tangent of the slope and the intercept obtained by extrapolation. The problem is by means of the tangent and intercept to obtain the three unknowns you have in Eq. 8. I am not able, at the present moment, to say whether it would be necessary to use one capillary tube or two, but Mr. Buckingham is still working on the problem and I hope that he will tell us the easiest method to find the three unknowns.

Mr. Green.

MR. HENRY GREEN.—I should like to express my great appreciation of Mr. Buckingham's work. I do not think that an apology need be made for the Bingham formula. It has certainly served a useful purpose and perhaps will continue to do so for some time to come. Its chief virtue is its great simplicity. However, if the new formula proves to be correct, then the old one must go, for the results it gives cannot then even be considered approximate. In a way this is to be regretted, as Mr. Buckingham's formula is somewht complicated, and, as it stands now, requires an excessive amount of time for calculation. Still if progress has been made, and I believe it has, no real harm has been done and our next step must be directed toward the simplification of the vast amount of new material which Mr. Buckingham has put at our disposal.

Mr. Bingham.

MR. E. C. BINGHAM.—Mr. Buckingham's investigation offers us a possible explanation of the curvature found in the flow-shearing stress curves; but, as I pointed out in 1916, there may be still other explanations of the curvature, such as seepage, which is not taken account of at all in Mr. Buckingham's formulas. From a practical point of view, it is not very satisfactory to have to use a formula which is not linear and which requires the estimation of the thickness of the still hypothetical slippage layer.

Mr. Bingham. Rather than further complicate our formula in actual practice, it would seem to me a much better plan to so change the conditions of flow that the formula will be linear and the slippage and seepage terms rendered negligible. It must be remembered that the published experimental data in this field are as yet very limited. According to experiments of Mr. Hyden and myself, it appears possible to obtain flow-shearing stress curves which are quite linear by a suitable choice of conditions. Fortunately Mr. Buckingham's formulas reduce to a linear form very similar to my own, when the shearing stresses are large. His value of p is in fact exactly one-third greater than our own, his definition of the friction or yield value being different from that given by me.[1]

Mr. MacGregor. MR. J. R. MACGREGOR.—I am not going to go into the academic aspect of the question at all, but I wonder if there has been observed a difference in the slippage when you have two plastics that flow at the same rate, and when the vehicle used in one instance is more viscous than in another. Plasticity can be developed by a large amount of pigment in a thin liquid and a small amount in a viscous liquid.

Mr. Green. MR. GREEN.—Mr. MacGregor has used "plasticity" as a comparable quantity, which makes it rather difficult for me to answer his question. I should first like to have his definition of this term so as not to cause confusion in the discussion.

Mr. MacGregor. MR. MACGREGOR.—For instance, in a paint we can develop a certain body, that is what we mean by plastic flow, a certain mobility, and while you can get exactly the same characteristics by using two different pigments in one liquid, I am wondering if you have found whether two liquids make a paint of approximately the same plastic flow—have I used the expression that you object to?—whether you get a greater or less slippage, or whether the slippage is the same in each case.

Mr. Green. MR. GREEN.—Viscous slip is a function of the viscosity of the vehicle, the thickness of the viscous layer and, of course, the radius and length of the capillary. The thickness of the viscous layer in turn is a function of the percentage volume of pigment present, the size and shape of the pigment particles and also the extent to which they are wet by the vehicle. As these variables are independent of each other it is hardly conceivable that an answer to Mr. MacGregor's question can be theoretically derived.

I would not be at all surprised, however, if it were found possible to *select these variables in such a manner* so that, of two different paints (in composition) giving the same yield values and mobilities and passed through the same capillary, the one containing the more viscous vehicle could be made to give the greater slippage. **Mr. Green.**

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[1] *Bulletin No. 13*, Bureau of Standards, p. 331 (1916).

Mr. Buckingham. MR. E. BUCKINGHAM (*Author's closure by letter*).—Replying to Mr. Green: It is, of course, quite obvious that a formula so complicated as Eq. 8 is of no practical value as it stands, if all the terms have to be used. The first requirement, however, is to develop the general equation which results from the hypotheses adopted, and to find out by trial whether the equation describes the observed facts. For if it does not, the hypotheses are incorrect and it is useless to follow them up. If, on the other hand, this first test of the hypotheses is favorable, it is then in order to see whether the equation can not be simplified so as to be of some practical value.

To settle this question at all generally would require the examination of more experimental data than are as yet available; but I may mention certain results I have obtained since the paper was read, by comparing the general Eq. 8 with the data given by Messrs. Bingham and Green on p. 658, of Vol. XIX, Part II, *Proceedings*, Am. Soc. Test. Mats.

The first question is whether we can get anything from the asymptote alone or, practically, from the straight part of the curve,—the equation of the asymptote being merely Eq. 8 with the term $p^4/3P^3$ omitted.

If the value of $\epsilon\phi$ is independent of the speed of flow, the equation of the asymptote is in the form

$$\frac{V}{t} = A\ (P - B) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

and the fact that the higher part of each curve of V/t against P is sensibly straight justifies the assumption that $\epsilon\phi$ is independent of V/t. To use the observations, I plotted them, drew the straight lines, and read off the values of the slope A and intercept B.

The coefficient A involves both μ and $\epsilon\phi$. The mobility μ is a constant of the material, by the fundamental hypothesis embodied in Eq. 1; but to go farther it is necessary to make some assumption regarding $\epsilon\phi$. The simplest is that $\epsilon\phi$ is also a constant of the material, but if we apply this assumption to the observations on the same material flowing through the three capillaries, we obtain values of the mobility which differ in the ratio nearly 4 to 1. This assumption is therefore incorrect.

The next simplest assumption is that $\epsilon\phi$ is proportional to the tube radius R. This fits the observations very well but, unfortunately, it does not permit of determining μ, f, and $\epsilon\phi$ separately but only the

Mr. Buckingham.

values of μf and of $\left(\frac{\mu + 4\epsilon\phi}{R}\right)$. The agreement is shown by the following table:

	$f\mu$	$\mu + \frac{4\epsilon\phi}{R}$
Tube III	31.5	499
" VI	29.5	419
" S	30.1	521
Means	30.4	480

To find the values of μ, f, and $\epsilon\phi$ separately, it is necessary to use the complete Eq. 8, including the term $p^4/3P^3$ which gives the curvature; and unless the points at the lower pressures, which are distinctly above the straight line are well determined, the results will be unsatisfactory. In the present instance the observations seem to be good, for by using all the six points for each tube we get the following approximate values:

	μ	f	$\frac{4\epsilon\phi}{R}$
Tube III	132	0.243	346
" VI	116	0.252	285
" S	131	0.246	371
Means	126	0.247	334

From the means we get $\mu f = 31.1$ and $\mu + \frac{4\epsilon\phi}{R} = 460$, as compared with 30.4 and 480 obtained from the slope and intercept of the asymptote. The foregoing values are not expressed in absolute units but are consistent.

The conclusions to be drawn from the foregoing are as follows:

1. For this particular paint, the assumption embodied in Eq. 1 supplemented by Mr. Green's conception of viscous slip in the quantitative form I have given it, does represent the observed facts quite as well as could have been expected in view of the unavoidable errors of measurement: μ and f are constants of the paint, while $\epsilon\phi$ is proportional to the radius of the tube but otherwise constant.

2. The values of μ and f can not be determined from the straight part of the curve alone.

3. If the slip were negligible, $\mu + \frac{4\epsilon\phi}{R}$ would be sensibly identical with μ and it would then be possible to find μ and f separately from the asymptote. But in the present case, as is seen from the second table

Mr. Buckingham.

of this discussion, the slip term is large so that the separation is impossible.

4. To reduce the importance of slip it is necessary to use not small but *large* tubes. Whether the effects of slip can thus be reduced to insignificance remains to be seen. If they can, the general Eq. 8 may be simplified by omitting the last term, and it will then also be possible to work from the asymptote alone, *i. e.*, to omit the term $p^4/3P^3$ and so have an equation of the same general form as used by Messrs. Bingham and Green.

Replying to Mr. Bingham: Referring to the last sentence, it may be remarked that my $p = 2lf/R$ is not one-third greater than his but identical with it, as may be seen by examining pages 486–487, Vol. XX, Part II, *Proceedings*, Am. Soc. Test. Mats., where he gives what is presumably his latest and preferred mathematical discussion of the subject. The difference between our results is not due to a difference of definition but to an oversight on his part.

A STUDY OF ELASTIC VISCOUS DEFORMATION.

By P. G. Nutting.

The mathematical form of the deformation function of stress and time, $s(t, F)$, must remain empirical until a foundation in molecular physics has been laid. It is rather startling, not to say alarming, to inspect the foundations upon which our great structures dealing with the theories of elasticity and hydrodynamics are erected. Everywhere in elasticity we find the initial assumption $\delta s/\delta F =$ constant (Hooke's Law), and in hydrodynamics, $\delta s/\delta t$ proportional to F, made without question, while neither holds with more than first order precision and over but narrow ranges of times and forces. Hooke's Law is sufficiently exact for most practical purposes in dealing with elastic materials and the law of viscosity is likewise sufficiently exact for dealing with the flow of many fluids. It is evident that each law must be a special case of a more general law involving both time and force and both storage and dissipation of energy. In our search for such a law, one of the by-products has been some information relating to the properties of materials which may be of interest to this Society.

The line of attack has been the study of materials possessing both elastic and viscous properties. In many of these the steady state is attained only after several minutes, not years or centuries on the one hand, nor hundredths of a second on the other as in the case of most ordinary materials. By this means we were enabled to determine the form of the time function during the initial stages of deformation and of the force function far beyond the elastic limit.

Instrument Developed.

The form of instrument finally adopted after several preliminary trials was such as to give a pure coplanar shear. Referring to Fig. 1, it consists essentially of a steel tongue between a pair of fixed steel plates from which it is separated by spaces 2 mm. thick and 50 by 100 mm. in area. The material to be tested is cast in these spaces. The tongue is drawn out by known forces ($\frac{1}{2}$, 1, 2, 4 and 8 kg.), its displacement being noted after given intervals of time (0, 15, 30 and 45 seconds, 1, 2, 3—10 minutes). Fig. 2 is a reproduction of a photograph of the instrument.

Reading the displacement by means of a microscope was discarded in favor of a mechanical magnification much more convenient, sensitive and free from systematic error. The end of the moving tongue passes between a pair of rollers carrying mirrors reflecting the image of a lamp filament on a scale, or carrying a light pointer (in work on soft materials) moving on a circular scale. Magnifications of 50 to 100 times the displacement are readily obtained by this means, while systematic errors are practically all eliminated. The displacements to be measured are from 0 to about 0.5 mm. and are read to better than 1 per cent. Temperature control must be close since the properties of all materials of this class vary rapidly with temperature. Fresh cast material is in most cases stiffer, but in some cases softer than after strain and rest. Data quoted below refers to material in a steady state. Measurements on hydrolene, repeated after three months' rest, checked to within errors of observation.

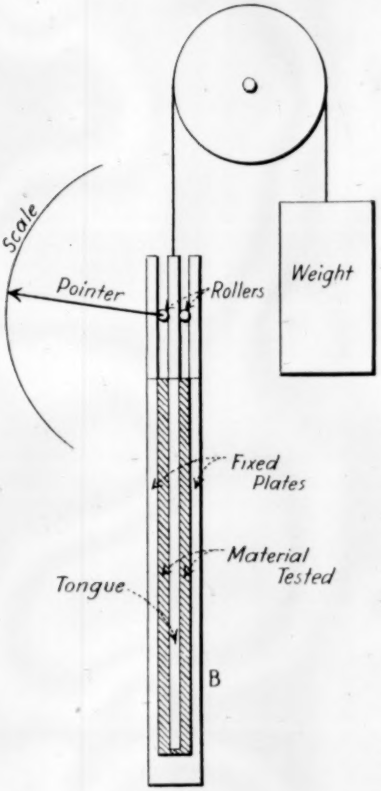

FIG. 1.

DISCUSSION OF VISCOUS DEFORMATION.

It was found that the laws of viscosity ordinarily assumed did not in general apply, although one very stiff pitch (hydrolene) was found which behaved like a very viscous fluid. The shearing strain is not in general proportional either to the shearing stress or to the time it has been applied. Viscosity, taken as the ratio of force per unit area to rate of shear, is not a constant but varies with the force as shown in Fig. 3.

It is to be noted that three of the four substances show wide variations of "viscosity" with force. The loaded tarvia is apparently stiffer the greater the force applied, the others softer. In mathematical terms, calling strain s, time t and stress F, for viscous deformation it has always been assumed that deformation is proportional to time and force, and velocity proportional to force and independent of time:

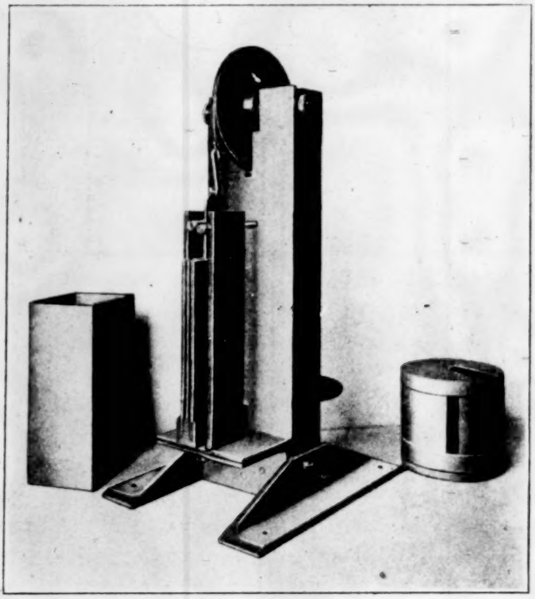

FIG. 2.

$$s = a\,t\,F \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$v = \frac{ds}{dt} = a\,F \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

in which a is a constant depending upon the units and dimensions employed. Such relations do not hold for these materials nor does it help matters in the least to add an elastic term to the displacement s, since elastic displacement cannot continue indefinitely with time.

EXPERIMENTAL DATA.

Eqs. 1 and 2 must be expressed in a more general form if they are to be applicable to all materials. It seemed probable from preliminary work that the more general equation would be of the same form as Eqs. 1 and 2 combined, save that the quantities t and F would have exponents which are not equal to unity for any but special cases. Accordingly several materials were tested in which first F and then t were kept constant, and in this way it was found that the test data could be expressed by a general formula in which t and F have exponents not equal to unity.

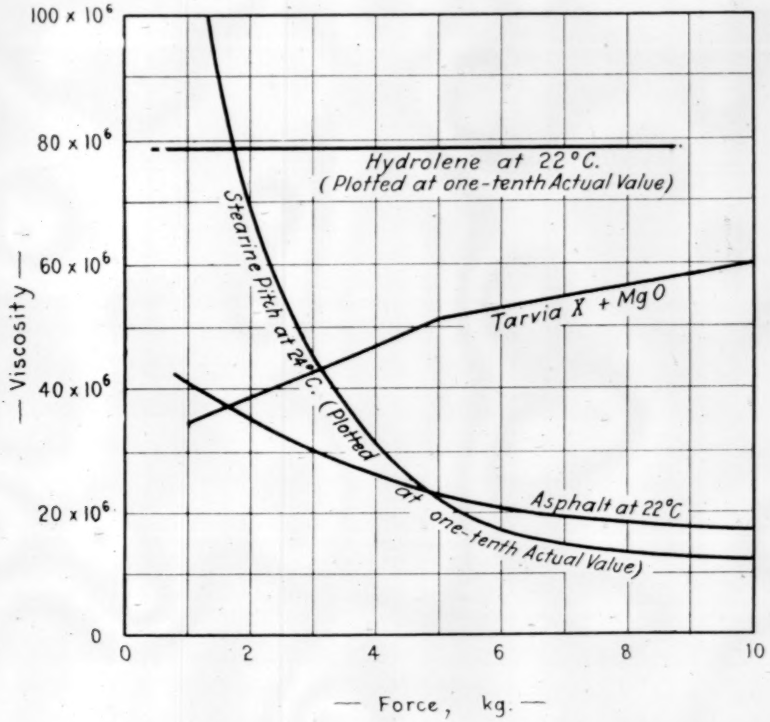

FIG. 3.—Variation of Viscosity with Force.

Fig. 4 shows the relation between deformation and time for a hard stearine pitch, using three values of F: 3.0, 5.3, and 8.0 kg. In the figure the ordinates are scale displacements (80 times the actual displacements) and the abscissas are times expressed in minutes. The elastic relaxation after removal of the weights is also shown in the figure.

These curves are of parabolic type, $s = k\ t^n$. Plotting log s against log t and solving for n in $\delta s/s = n\delta t/t$, n is found to be 0.56. There is no systematic variation from the linear relation between log s and log t. The relaxation after the force is removed is large and continues for a long time. The first part of the relaxation curve is almost identical with the original displacement curve—a matter of great theoretical interest. The total relaxation is greater the greater the initial strain.

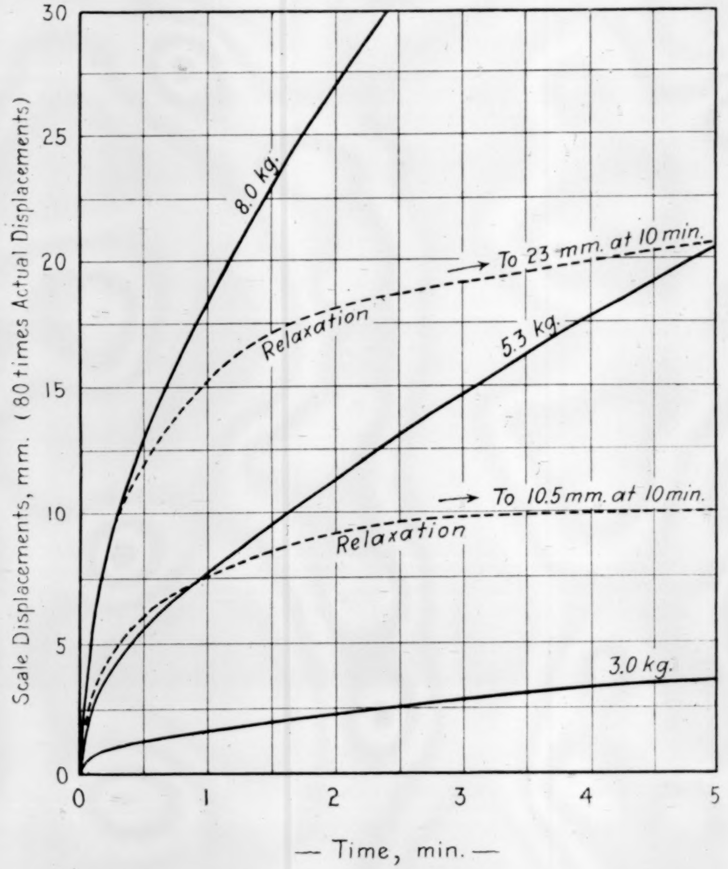

FIG. 4.—Deformation of Hard Stearine Pitch.

By a similar procedure, taking constant times, log s is found to be also a linear function of the force F, namely $s = cF^m$ without systematic variation as the time is varied. The general relation between deformation, time and force is then

$$s = at^nF^m \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The value of m for the stearine pitch tested is 2.0. The constant a is 0.28 for this pitch at 24° C., if s represents scale deflection in millimeters, t time in minutes and F force in kilograms. The complete formula becomes

$$s = 0.28\, t^{0.56} F^{2.0} \qquad (4)$$

Similar relations have been found to hold for all the other substances investigated. The constants found are tabulated below,

CONSTANTS OF EQ. 3.

	a.	n.	m.
Asphalt, 22° C.	3.5	0.87	1.27
Hydrolene (140°), 22° C.	0.66	0.40	1.14
Stearine pitch (hard), 24° C.	0.28	0.56	2.0
Tarvia X 60 per cent+MgO 40 per cent, 23° C.	1.72	0.56	0.74
Stearine pitch (soft), 0° C.	0.39	0.52	1.32
" " " 11° C.	78.5	0.91	1.4

In no case is either n or m unity. The time exponent n is always less than unity but approaches that value in the softer materials. The force exponent m may be either greater or less than unity, a high value indicating a rubbery texture, while a value less than unity indicates a texture resembling quicksand, the yield being relatively less and less as the stress is increased. In the special cases of purely viscous and purely elastic yield, $m = 1$, a case approached by hydrolene.

Considering the yield during the first minute, $t = 1$ and $s = aF^m$, the effect of the variation in m is shown in Fig. 4, which gives first minute displacements for various forces. The curves show clearly the convexity downward due to m greater than unity and the converse. For hydrolene, m is so nearly unity that s is very nearly proportional to F. The loaded tarvia X ($m = 0.74$) has properties decidedly like quicksand.

CONCLUSIONS.

The interpretation and application of these preliminary results promise wide usefulness. They indicate that:

1. Plastics possess very definite characteristic properties upon which their technical application largely depends.

2. A simple instrument, giving results of ample precision, has been developed for the study of a wide range of viscous, plastic and elastic behavior.

3. A new relation between deformation and stress and time has been obtained: $s = at^nF^m$. This is of such generality as to include as special cases the relations ordinarily assumed to hold for elastic solids ($n = 0$ and $m = 1$) and for viscous fluids ($n = 1$ and

$m = 1$). Viscosity determinations by means of either the falling ball method or by the rate of flow through a small tube are based on the assumption of velocity proportional to the force maintaining it (that is, $n = 1$ and $m = 1$). The new formula is applicable for clearing up the many difficulties and inconsistencies encountered. Hooke's Law for solids amounts to a single statement that $m = 1$ and $n = 0$.

4. Melting, softening, dropping and other thermal points may be precisely defined by means of the new formula, namely by assigning specific values to any or all of the constants a, n and m, while s, t and F are measured in specified units.

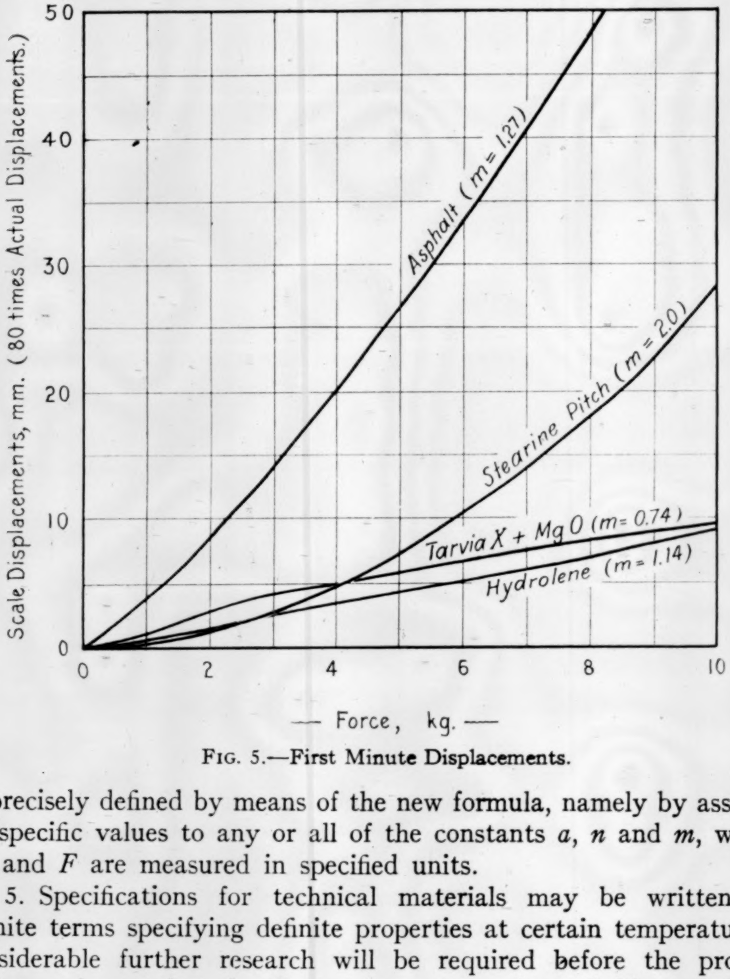

FIG. 5.—First Minute Displacements.

5. Specifications for technical materials may be written in definite terms specifying definite properties at certain temperatures. Considerable further research will be required before the proper limits can be set, but the necessary apparatus is available and these preliminary results indicate the nature of the specifications and the means of determining them.

DISCUSSION.

Mr. E. C. Bingham.—A large number of experiments have been made on the viscosity of solids by various experimenters, such as Barns, Trouton and Andrews. It has been noted that the rate of deformation decreases with the length of time of application of the stress, etc., the data being published in great detail. A close study of these data leads to the belief that they may be represented by an exponential formula of the type given by Mr. Nutting, but it does not lead us to usable and definitely measurable quantities such as I hope that yield value and mobility will prove to be. The very generality of Mr. Nutting's equation is its fatal defect from a practical point of view. **Mr. Bingham.**

The most important thing in measurements of plastic flow is to choose the conditions of flow so that the simple linear formula

$$\frac{dv}{dx} = \mu\ (F\text{-}f)$$

will apply, which I explained in 1916.[1] If we can do this we come directly to two properties of the material which are independent of the instrument used in their determination.

To illustrate my meaning, let me draw an analogy from the study of viscous flow. At the beginning of the last century classical researches on hydraulic flow were made in France, and the fundamental laws of motion were laid down by Navier, Poisson and others, in elaborate mathematical reasoning. Now viscosity doubtless plays a part in the hydraulic flow of liquids through pipes. But all of this work contributed *nothing* to our practical knowledge of viscosity. It was not until Poiseuille, nearly a half century later, had the happy thought of studying flow in narrow capillary tubes that the conditions became such that the fundamental law of viscous flow

$$\frac{dv}{dx} = \phi\ F$$

was established and the subsequent valuable work on viscosity by Maxwell, O. E. Meyer and others became possible.

In conclusion, I should like to suggest the desirability of changing the conditions of flow in Mr. Nutting's apparatus so that the expo-

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[1] *Bulletin No. 278*, Bureau of Standards (1916).

Mr. Bingham. nential formula may be avoided on the ground that the exponential formula is incapable of easy interpretation.

Mr. Herschel. MR. W. H. HERSCHEL.—Progress in viscosimetry has been accomplished by experimenters noting that when they determined viscosity at different velocities, their results did not agree, and by proceeding to determine the error in their apparatus, they have arrived at more exact methods of measuring viscosity. Mr. Nutting, instead of following this usual course, has taken the ground that because his results did not agree with the definition of viscosity, therefore the definition of viscosity was wrong. I will admit that there is some confusion in the paper due to the fact that it is not at all clear whether Mr. Nutting is familiar with the work of Bingham and Green, and whether he realizes the possibility that the material with which he experimented was a plastic and not a viscous substance. To say that the laws of viscosity do not apply to materials which are not viscous is not a very important discovery. Now you will note, in Fig. 3 of this paper, that there is one material which was viscous and to which the theoretical laws apply. We may therefore assume that the discrepancy with the theory (noted by Mr. Nutting) is not due to a defect in the instrument, probably, but to a defect in the material; in other words, the material is plastic. Now if we consider this paper from the point of view of a discovery that the law of viscosity is in error, then we may say that that has been claimed before and is nothing new and is erroneous; but if we look at this paper from the point of view of a new law of plastic material, then we may say that the laws of plastic material have not been very well formulated as yet. The last word has not been said, and it is simply a question whether these laws are more accurate and more easy to use than other laws that have hitherto been presented.

Mr. Green. MR. HENRY GREEN.—Mr. Nutting states in his paper that "Temperature control must be close since the properties of all materials of this class vary rapidly with temperature." It is perfectly true that this is of vital importance, yet nowhere in the paper does it appear how this control was maintained nor how the temperature was measured. As very little of the energy input is used in the production of surface or transformed into kinetic energy, it is evident that it is employed in overcoming viscous resistance, which means it is eventually dissipated in the form of heat. As an increase in temperature will produce a more fluid material it would seem most natural to explain Mr. Nutting's time effect as due to a decrease in viscosity from the accumulating heat developed as the steel tongue is pulled from the pitch. In fact I do not see how it is possible to admit the existence of a time effect until it is first definitely established that there is no accumulation of heat in the material during the experiment. **Mr. Green.**

In regard to Fig. 3, the curve marked "Tarvia X + MgO" is the only one which appears to be in any way new. Hydrolene is a true liquid beyond doubt. The two remaining curves are evidently plastic materials in which no recognition has been taken of their yield values, hence the apparent (but not actual) increase in "viscosity" with decrease of force.

MR. R. E. WILSON.—I wish to take a ground somewhat between that of Mr. Nutting and Mr. Herschel, in that I believe that Mr. Nutting, in so far as the evidence before us now shows, is probably very close to the fundamentals of the laws of flow of solids. However, the methods which Bingham and Green have worked out, by using large forces in very small capillaries so as to secure very slow rates of flow, and thus practically eliminate the effect of the troublesome variable of time, have given us a practical method of measurement which is what we need. As Mr. Bingham has said, as long as we tried to measure viscosity in small tubes, we had very complicated formulas; they were absolutely correct, but they were too complicated for most practical purposes. When we went to the long straight tubes, measuring very slow rates of flow under special conditions, we found that very simple laws and usable laws hold. **Mr. Wilson.**

MR. GREEN.—Mr. Buckingham's paper presented on Tuesday has shed considerable light on plastic flow through capillaries. Among other things it clearly shows that yield value is, at present, an *unknown* function of the intercept of the asymptote on the pressure axis. Consequently we can derive neither yield value nor mobility from the straight part of the curve until more is known of the mathematics involved. **Mr. Green.**

MR. HERSCHEL.—I think there is a fundamental difference between Mr. Buckingham's and Mr. Bingham's views, that is not overcome by high pressure. According to Mr. Bingham, there are two constants which determine the nature of the material. According to Mr. Green's observations with a microscope to which Mr. Buckingham has applied mathematical treatment, there are three constants; therefore if you determine two constants by using high pressures, you cannot possibly arrive at the same result as if you determine three constants. **Mr. Herschel.**

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VOLUME 21.

SUBJECT INDEX

A

Aggregates.
  A Study of the Composition of Blast-Furnace Slags Suitable for Concrete —. L. G. Carmick, 976. Discussion, 982.
  Concrete and Concrete —. Report of Committee C-9, 317. Discussion, 322.
  Tentative Specifications for Concrete —, 544.
  Tentative Methods of Test for Sieve Analysis of — for Concrete, 586.
Alloys.
  Non-Ferrous Metals and —. Report of Committee B-2, 198. Addendum, 208.
  Tentative Methods of Chemical Analysis of Aluminum and Light Aluminum —, 499.
  Tentative Revision of the Standard Definitions and Rules Governing the Preparation of Micrographs of Metals and —, 838.
  Tentative Specifications for Non-Ferrous — for Railway Equipment in Ingots, Castings, and Finished Car and Tender Bearings, 486.
Aluminum.
  Tentative Methods of Chemical Analysis of — and Light — Alloys, 499.
Analysis.
  Tentative Methods of Chemical — of Aluminum and Light Aluminum Alloys, 499.
  Tentative Methods of Chemical — of Limestone, Lime and Hydrated Lime, 565.
  Tentative Methods of Chemical — of Nickel, 522.
  Tentative Methods of Test for Sieve — of Aggregates for Concrete, 586.
  Tentative Revision of Standard Methods of Laboratory Sampling and — of Coal, 837.
Annual Address.
  — by the President, George S. Webster, 39.
Annual Meeting.
  Summary of the Proceedings of the Twenty-fourth —, 11.
Apparatus.
  Improvements in — for Testing Petroleum Products. T. G. Delbridge, 1100.
Asphalt.
  Tentative Specifications for — Cement, 40 to 50 Penetration, 681.
  Tentative Specifications for — Cement, 50 to 60 Penetration, 682.
  Tentative Specifications for — Cement, 60 to 70 Penetration, 683.
  Tentative Specifications for — Cement, 70 to 90 Penetration, 684.
  Tentative Specifications for — Cement, 90 to 120 Penetration, 685.

B

Bar, Bars.
  Methods of Casting Manganese-Bronze Test — as a Check on Melts of Small Castings. E. H. Dix, Jr., 912. Discussions, 919.
  Tentative Specifications for Merchant — Iron, 474.

Bearings.
Tentative Specifications for Non-Ferrous Alloys for Railway Equipment in Ingots, Castings, and Finished Car and Tender —, 486.

Belting.
Tentative Specifications for Rubber — for Power Transmission, 795.

Bituminous.
Tentative Methods of Test for Ductility of — Materials, 704.
Tentative Methods of Test for Water in — Materials, 706.

Blast-Furnace Slags.
A Study of the Composition of — Suitable for Concrete Aggregate. L. G. Carmick, 976. Discussion, 982.

Board.
Tentative Specifications for Gypsum Wall —, 560.
Tentative Specifications for Gypsum Plaster —, 562.

Boiler.
Tentative Specifications for — and Firebox Steel for Stationary Service, 447.
Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron — Tubes, 461.

Boxes.
Tentative Specifications for 4-One — and Similar Type —, 741.

Brass.
Tentative Specifications for — Ingot Metal, Graded and Ungraded, for Sand Castings, 491.

Brick.
—. Report of Committee C-3, 284.
Tentative Specifications for Clay Sewer —, 527.
Tentative Methods of Test for Resistance of Fire-Clay — to Spalling Action, 577.

Bronze.
Methods of Casting Manganese — Test Bars as a Check on Melts of Small Castings. E. H. Dix, Jr., 912. Discussion, 919.

Building Tile.
Hollow —. Report of Committee C-10, 324.
Tentative Specifications for Clay Hollow —, 547.

C

Cable.
Tentative Specifications for Insulated Wire and —: 30-per-cent Hevea Rubber, 746.

Calcium Chloride.
Tentative Specifications for — for Dust Prevention, 679.

Car.
Tentative Specifications for Cast-Iron — Wheels, 481.
Tentative Specifications for Non-Ferrous Alloys for Railway Equipment in Ingots, Castings, and Finished — and Tender Bearings, 486.

Cast.
Impact Tests on — Steel. F. C. Langenberg, 840. Discussion, 850.

Casting, Castings.
Methods of — Manganese-Bronze Test Bars as a Check on Melts of Small —. E. H. Dix, Jr., 912. Discussion, 919.
Tentative Specifications for Non-Ferrous Alloys for Railway Equipment in Ingots, —, and Finished Car and Tender Bearings, 486.

Casting, Castings (*Continued*):
  Tentative Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand —, 491.
Cast-Iron.
  —. Report of Committee A -3, 96. Addendum, 98.
  Tentative Specifications for — Car Wheels, 481.
  Some Failures of — Wheels. H. J. Force, 891. Discussion, 897.
Cement.
  Clay and — Sewer Pipe. Report of Committee C-4, 285.
  Tentative Specifications for Asphalt —, 40 to 50 Penetration, 681.
  Tentative Specifications for Asphalt —, 50 to 60 Penetration, 682.
  Tentative Specifications for Asphalt —, 60 to 70 Penetration, 683.
  Tentative Specifications for Asphalt —, 70 to 90 Penetration, 684.
  Tentative Specifications for Asphalt —, 90 to 120 Penetration, 685.
  Tentative Specifications for High-Carbon Tar — for Use Cold in Repair Work (Cut-Back Product), 690.
  Tentative Specifications for Low-Carbon Tar — for Use Cold in Repair Work (Cut-Back Product), 692.
  Tentative Specifications for High-Carbon Tar —, 698.
  Tentative Specifications for Low-Carbon Tar —, 700.
  Tentative Revision of Standard Specifications and Tests for Portland —, 835.
  Testing of Plastic Calcined Magnesite for Use in Oxychloride —. M. Y. Seaston. 1039.
Centrifuge.
  Tentative Methods of Test for Water and Sediment in Petroleum Products, by Means of —, 670.
Chain.
  Tentative Specifications for Iron and Steel —, 468.
Chemical Analysis.
  Tentative Methods of — of Aluminum and Light Aluminum Alloys, 499.
  Tentative Methods of — of Nickel, 522.
  Tentative Methods of — of Limestone, Lime and Hydrated Lime, 565.
Clay.
  — and Cement Sewer Pipe. Report of Committee C-4, 285.
  Tentative Specifications for — Sewer Brick, 527.
  Tentative Specifications for — Hollow Building Tile, 547.
  Tentative Methods of Test for Resistance of Fire — Brick to Spalling Action, 577.
Cloth.
  Screen Wire —. Report of Committee D-14, 427.
Cloud.
  — and Pour Test. Report of Sub-Committee XVI, Committee D-2, 374.
  Tentative Methods of Test for — and Pour Points of Petroleum Products, 674.
Coal.
  —. Report of Committee D-5, 381.
  Tentative Revision of Standard Methods of Laboratory Sampling and Analysis of —, 837.
  Tentative Specifications for — Tar Pitch for Block Filler, 702.
Coatings.
  Preservative Metallic —. Report of Sub-Committee II, Committee A-5, 105.
  Preservative — for Structural Materials. Report of Committee D-1, 329.

Coke.
—. Report of Committee D-6, 383.
Tentative Definitions of Terms Relating to —, 708.

Color.
—. Report of Sub-Committee VI, Committee D-2, 363.
The Use of Secondary Reference Standards in Process Problems of — Measurement. H. S. Busby, 1139. Discussion, 1147.

Concrete.
A Comparison of the Results of the Slump Test and the Flow Table in the Measurement of the Consistency of —. W. L. Schwalbe, 983. Discussion, 988.
A Proposed Method of Estimating the Density and Strength of — and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and —. A. N. Talbot, 940. Discussion, 968.
A Study of the Composition of the Blast-Furnace Slags Suitable for — Aggregate. L. G. Carmick, 976. Discussion, 982.
Cooperative Tests on Effect of Hydrated Lime on — Mixtures. Report of Committee C-7, Appendix, 294. Discussion, 302.
— and — Aggregates. Report of Committee C-9, 317. Discussion, 322.
Progress Report of the Joint Committee on Standard Specifications for — and Reinforced —, 212.
Reinforced —. Report of Committee C-2, 210.
Tentative Methods of Making Compression Tests of —, 579.
Tentative Specifications for Cold-Drawn Steel Wire for — Reinforcement, 459.
Tentative Specifications for — Aggregates, 544.
Tentative Method of Test for Organic Impurities in Sand for —, 585.
Tentative Method of Test for Sieve Analysis of Aggregates for —, 586.
Tentative Method of Securing Specimens of Hardened — from the Structure, 588.
Time of Set of —. Watson Davis, 995. Discussion, 1007.
Variation in the Effect of Rodding —. F. E. Giesecke, 1008.
Wear Tests of —. D. A. Abrams, 1013. Discussion, 1035.

Consistency.
A Comparison of the Results of the Slump Test and the Flow Table in the Measurement of the — of Concrete. W. L. Schwalbe, 983. Discussion, 988.

Copper Wire.
—. Report of Committee B-1, 195.

Corrosion.
— of Iron and Steel. Report of Committee A-5, 103. Discussion, 191.

Cotton.
Tentative Specifications for — Rubber-Lined Fire Hose for Private Fire Department Use, 773.
Tentative Specifications for — Rubber-Lined Fire Hose for Public Fire Department Use, 778.

D

Definitions.
— of Terms Used in Paint Specifications. Report of Sub-Committee VI, Committee D-1, 341.
Nomenclature and —. Report of Committee E-8, 440.

Definitions (*Continued*):
  Tentative — of Terms Relating to the Gypsum Industry, 600.
  Tentative — of Terms Relating to Hollow Tile, 602.
  Tentative — of Terms Relating to Paint Specifications, 629.
  Tentative — of Terms Relating to Coke, 708.
  Tentative — of Terms Relating to Mechanical Fabric, 814.
  Tentative — of Terms Relating to Metallography, 829.
  Tentative Revision of Standard — and Rules Governing the Preparation of Micrographs of Metals and Alloys, 838.
  Tentative Revision of Standard — of Terms Relating to Paint Specifications, 838.

Density.
  A Proposed Method of Estimating the — and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and Concrete. A. N. Talbot, 940. Discussion, 968.

Distillation.
  —. Report of Sub-Committee VIII, Committee D-2, 367.
  Tentative Method of Test for — of Gasoline, Naphtha, Kerosene and Similar Petroleum Products, 631.

Drain Tile.
  —. Report of Committee C-6, 286.

Ductility.
  Tentative Method of Test for — of Bituminous Materials, 704.

Dust.
  Tentative Specifications for Calcium Chloride for — Prevention, 679.

E

Elastic Viscous Deformation.
  A Study of —. P. G. Nutting, 1162. Discussion, 1169.

Executive Committee.
  Annual Report of the —, 47.

F

Fabric.
  Tentative Specifications for Imperfections and Tolerances in 60-in. 17¼-oz. Square-Woven Tire Builder —, 811.
  Tentative Definitions of Terms Relating to Mechanical —, 814.

Firebox Steel.
  Tentative Specifications for Boiler and — for Stationary Service, 447.

Fire-Clay.
  Tentative Method of Test for Resistance of — Brick to Spalling Action, 577.

Fire Point.
  Tentative Method of Test for Flash and — by Means of Open Cup, 651.

Flash.
  —. Report of Sub-Committee XII, Committee D-2, 368.
  Tentative Method of Test for — and Fire Points by Means of Open Cup, 651.
  Tentative Method of Test for — Point by Means of the Pensky-Martens Closed Tester, 655.

Flow Table.
  A Comparison of the Results of the Slump Test and the — in the Measurement of the Consistency of Concrete. W. L. Schwalbe, 983. Discussion, 988.

Forge.
Tentative Specifications for Steel Plates for — Welding, 454.
Fuel.
Tentative Method of Test for Viscosity of — Oils and Other Oils of Similar Viscosity, 642.

G

Gas.
— Absorbent Oil. Report of Sub-Committee II, Committee D-2, 360.
Gasoline.
Problems Involved in the Development of Specifications for Motor —. E. W. Dean, 1094.
Tentative Method of Test for Distillation of —, Naphtha, Kerosene and Similar Petroleum Products, 631.
Gloves.
Tentative Specifications for Rubber — for Electrical Workers on Apparatus or Circuits Not Exceeding 3000 Volts to Ground, 805.
Grease.
—. Report of Sub-Committee IV, Committee D-2, 361
Gypsum.
—. Report of Committee C-11, 326.
Tentative Definitions of Terms Relating to the — Industry, 600.
Tentative Methods of Testing — and — Products, 590.
Tentative Specifications for —, 553.
Tentative Specifications for Calcined —, 556
Tentative Specifications for — Plastering Sand, 559.
Tentative Specifications for — Wall Board, 560.
Tentative Specifications for — Plaster Board, 562.

H

Heat Treatment.
— of Iron and Steel. Report of Committee A-4, 99.
High Temperatures.
Comparative Tests of Steels at —. R. S. MacPherran, 852. Discussion, 861.
Oxidation at —. Report of Sub-Committee X, Committee D-2, 368.
Highways.
Tests for Soils with Relation to Their Use in the Subgrade of —. A. T. Goldbeck and F. H. Jackson, 1057.
Hollow Building Tile.
—. Report of Committee C-10, 324.
Tentative Specifications for Clay —, 547.
Hollow Tile.
Tentative Definitions of Terms Relating to —, 602.
Hose.
Tentative Specifications for Cotton Rubber-Lined Fire — for Private Fire Department Use, 773.
Tentative Specifications for Cotton Rubber-Lined Fire — for Public Fire Department Use, 778.
Tentative Specifications for Wrapped Air — for Use with Pneumatic Tools, 784.
Tentative Specifications for Braided Air — for Use with Pneumatic Tools, 788.
Tentative Specifications for Steam —, 792.

Hydrated Lime.
Cooperative Tests on Effect of — on Concrete Mixtures. Report of Committee C-7, Appendix, 294. Discussion, 302.
Tentative Specifications for — for Structural Purposes, 537.
Tentative Methods of Chemical Analysis of Limestone, Lime and —, 565.
Hydroxide.
Tentative Specifications for Iron Oxide and Iron —, 625.

I

Immersion.
Total — Tests. Report of Sub-Committee V, Committee A-5, 157.
Impact.
— Tests on Cast Steel. F. C. Langenberg, 840. Discussion, 850.
Measurement of —. E. B. Smith, 1073. Discussion, 1081.
Imperfections.
Tentative Specifications for — and Tolerances in 60-in. 17¼-oz. Square-Woven Tire Builder Fabric, 811.
Impurities.
Tentative Method of Test for Organic — in Sand for Concrete, 585.
Ingot, Ingots.
Tentative Specifications for Non-Ferrous Alloys for Railway Equipment in —, Castings, and Finished Car and Tender Bearings, 486.
Tentative Specifications for Brass — Metal, Graded and Ungraded, for Sand Castings, 491.
Inspection.
— of the Fort Sheridan, Pittsburgh and Annapolis Tests. Report of Sub-Committee III, Committee A-5, 106. Discussion, 191.
Report of — of Test Panels, October 1, 1920. Report of Committee D-1, Appendix, 348.
Insulating.
Electrical — Materials. Report of Committee D-9, 392.
Tentative Methods of Testing Molded — Materials, 711.
Tentative Methods of Testing — Varnishes, 722.
Tentative Specifications for Rubber — Tape, 802.
Iron.
Cast—. Report of Committee A-3, 96. Addendum, 98.
Corrosion of — and Steel. Report of Committee A-5, 103. Discussion, 191.
Heat Treatment of — and Steel. Report of Committee A-4, 99.
Preparation of — and Steel Surfaces for Painting. Report of Sub-Committee XIV, Committee D-1, 345.
Proposed Revisions of Standards and Tentative Standards for Wrought —. Report of Committee A-2, Appendix, 94.
Some Failures of Cast-— Wheels. H. J. Force, 891. Discussion, 897.
Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded — Boiler Tubes, 461.
Tentative Specifications for — and Steel Chain, 468.
Tentative Specifications for — Oxide and — Hydroxide, 625.
Tentative Specifications for Merchant Bar —, 474.
Tentative Specifications for Hollow Staybolt —, 478.
Tentative Specifications for Cast — Car Wheels, 481.
Tentative Methods of Metallographic Testing of — and Steel, 817.
Wrought —. Report of Committee A-2, 90.

K

Kerosene.
Tentative Method of Test for Distillation of Gasoline, Naphtha, — and Similar Petroleum Products, 631.

L

Lap-Welded.
Tentative Specifications for — and Seamless Steel and — Iron Boiler Tubes, 461.
Lead.
Tentative Specifications for Basic Carbonate White —, 619.
Tentative Specifications for Basic Sulfate White —, 621.
Tentative Specifications for Red —, 623.
Leaded.
Tentative Specifications for — Zinc Oxide, 617.
Lime.
Cooperative Tests on Effect of Hydrated — on Concrete Mixtures. Report of Committee C-7, Appendix, 294. Discussion, 302.
—. Report of Committee C-7, 289. Discussion, 302.
Tentative Specifications for Quicklime for Structural Purposes, 533.
Tentative Specifications for Hydrated — for Structural Purposes, 537.
Tentative Methods of Chemical Analysis of Limestone, — and Hydrated —, 565.
Limestone.
Tentative Methods of Chemical Analysis of —, Lime and Hydrated Lime, 565.
Linseed Oil.
—. Report of Sub-Committee V, Committee D-1, 334.
Tentative Specifications for Purity of Raw — from South American Seed, 613.
Tentative Specifications for Purity of Boiled — from South American Seed, 614.
Lubricants.
Petroleum Products and —. Report of Committee D-2, 351.
Lubricating.
Tentative Method of Test for Precipitation Number of — Oils, 648.

M

Magnesite.
Testing of Plastic Calcined — for Use in Oxychloride Cements. M. Y. Seaton, 1039.
Magnetic Testing.
— of Springs. T. Spooner and I. F. Kinnard, 883.
Manganese.
Methods of Casting —-Bronze Test Bars as a Check on Melts of Small Castings. E. H. Dix, Jr., 912. Discussion, 919.
Melting Point.
Tentative Methods of Test for — of Paraffin Wax, 638.
— of Petrolatum. Report of Sub-Committee I, Committee D-2, Appendix, 357.
Metal, Metals.
Non-Ferrous — and Alloys. Report of Committee B-2, 198. Addendum, 208.
Some Mechanical Properties of Hot-Rolled Monel —. P. D. Merica, R. G. Waltenberg, and A. S. McCabe, 922. Discussion, 939.
Tentative Specifications for Brass Ingot —, Graded and Ungraded, for Sand Castings, 491.
Tentative Revision of the Standard Definitions and Rules Governing the Preparation of Micrographs of — and Alloys, 838.

Metallic Coatings.
Preservative —. Report of Sub-Committee II, Committee A-5, 105.
Metallographic.
Tentative Methods of — Testing of Iron and Steel, 817.
Metallography.
—. Report of Committee E-4, 436.
Tentative Definitions of Terms Relating to —, 829.
Micrographs.
Tentative Revision of the Standard Definitions and Rules Governing the Preparation of — of Metals and Alloys, 838.
Monel Metal.
Some Mechanical Properties of Hot-Rolled —. P. D. Merica, R. G. Waltenberg, and A. S. McCabe, 922. Discussion, 939.
Mortar.
A Proposed Method of Estimating the Density and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in — and Concrete, 940. Discussion, 968.
Motor.
Problems Involved in the Development of Specifications for — Gasoline. E. W. Dean, 1094.

N

Naphtha.
Tentative Method of Test for Distillation of Gasoline, —, Kerosene and Similar Petroleum Products, 631.
Tentative Methods of Test for Sulfur in — and Illuminating Oils, 644.
Nickel.
Tentative Specifications for —, 495.
Tentative Methods of Chemical Analysis of —, 522.
Nomenclature.
— and Definitions. Report of Committee E-8, 440.
Non-Ferrous.
— Metals and Alloys. Report of Committee B-2, 198. Addendum, 208.
Tentative Specifications for — Alloys for Railway Equipment in Ingots, Castings, and Finished Car and Tender Bearings, 486.

O

Ocher.
Tentative Specifications for —, 627.
Oil, Oils.
Gas Absorbent —. Report of Sub-Committee II, Committee D-2, 360.
Joint Comparative Tests of Spark Gaps for Testing Transformer —. Report of Committee D-9, Appendix I, 397.
Linseed —. Report of Sub-Committee V, Committee D-1, 334.
Procedures in Sludging Tests for Transformer —, Report of Committee D-9, Appendix II, 407.
Results of Cooperative Work for Saponification Number on Mixture of — Submitted to Committee Members. Report of Sub-Committee XIII, Committee D-2, Appendix, 371.
Specifications for Pigments Dry and in — when Marketed in That Form. Report of Sub-Committee XV, Committee D-1, 350.

Oil, Oils (*Continued*):
  Stress-Strain Measurements on Films of Drying —, Paints and Varnishes. H. A. Nelson, 1111. Discussion, 1135.
  Tentative Specifications for Purity of Raw Linseed — from South American Seed, 613.
  Tentative Specifications for Purity of Boiled Linseed — from South American Seed, 614.
  Tentative Method of Test for Precipitation Number of Lubricating —, 648.
  Tentative Methods of Testing Transformer and Switch —, 737.
  Tentative Method of Test for Viscosity of Fuel — and Other — of Similar Viscosity, 642.
  Tentative Method of Test for Sulfur in Naphthas and Illuminating —, 644.
  Tentative Revision of Standard Specifications for Purity of Raw Tung —, 835.

Open Cup.
  Tentative Method of Test for Flash and Fire Points by Means of —, 651.

Organic.
  Tentative Method of Test for — Impurities in Sand for Concrete, 585.

Oxidation.
  — at High Temperatures. Report of Sub-Committee X, Committee D-2, 368.

Oxide.
  Tentative Specifications for Iron — and Iron Hydroxide, 625.
  Tentative Specifications for Leaded Zinc —, 617.
  Tentative Specifications for Zinc —, 615.

Oxychloride.
  Testing of Plastic Calcined Magnesite for Use in — Cements. M. Y. Seaton, 1039.

P

Paint.
  Definitions of Terms Used in — Specifications. Report of Sub-Committee VI, Committee D-1, 341.
  — Thinners Other than Turpentine. Report of Sub-Committee XI, Committee D-1, 342.
  Stress-Strain Measurements on Films of Drying Oils, — and Varnishes. H. A. Nelson, 1111. Discussion, 1135.
  Testing of — Vehicles. Report of Sub-Committee III, Committee D-1, 333.
  Tentative Definitions of Terms Relating to — Specifications, 629.
  Tentative Revision of Standard Definitions of Terms Relating to — Specifications, 838.

Painting.
  Preparation of Iron and Steel Surfaces for —. Report of Sub-Committee XIV, Committee D-1, 345.

Papers.
  — and Publications. Report of Committee E-6, 437.

Paraffin.
  — Wax. Report of Sub-Committee III, Committee D-2, 360.
  Tentative Method of Test for Melting Point of — Wax, 638.

Paving Materials.
  Road and — . Report of Committee D-4, 375.

Pensky-Martens.
  Tentative Methods of Test for Flash Point by Means of the — Closed Tester, 655.

Petrolatum.
—. Report of Sub-Committee I, Committee D-2, 354.
Melting Point of —. Report of Sub-Committee I, Committee D-2, Appendix, 357.
Petroleum.
Improvements in Apparatus for Testing — Products. T. G. Delbridge, 1100.
— Products and Lubricants. Report of Committee D-2, 351.
Tentative Method of Test for Distillation of Gasoline, Naphtha, Kerosene and Similar — Products, 631.
Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in — Products, 643.
Tentative Method of Test for Water in — Products, 666.
Tentative Method of Test for Water and Sediment in — Products, by Means of Centrifuge, 670.
Tentative Method of Test for Cloud and Pour Points of — Products, 674.
The Refining of —. C. K. Francis, 1086.
Pigments.
Specifications for — Dry and in Oil when Marketed in That Form. Report of Sub-Committee XV, Committee D-1, 350.
Pipe.
Clay and Cement Sewer —. Report of Committee C-4, 285.
Pitch.
Tentative Specifications for Coal-Tar — for Block Filler, 702.
Plaster Board.
Tentative Specifications for Gypsum —, 562.
Plastering.
Tentative Specifications for Gypsum — Sand, 559.
Plastic Flow.
On — Through Capillary Tubes. E. Buckingham, 1154. Discussion, 1157.
Plates.
Tentative Specifications for Steel — for Forge Welding, 454.
Pneumatic.
Tentative Specifications for Wrapped Air Hose for Use with — Tools, 784.
Tentative Specifications for Braided Air Hose for Use with — Tools, 788.
Porcelain.
A Method of Determining the Tensile Strength of —. F. H. Riddle and J. S. Laird, 1050.
Tentative Methods of Testing Electrical —, 727.
Pour Point.
Tentative Method of Test for Cloud and — of Petroleum Products, 674.
Pour Test.
Cloud and —. Report of Sub-Committee XVI, Committee D-2, 374.
Precipitation.
—. Report of Sub-Committee IX, Committee D-2, 367.
Tentative Methods of Test for — Number of Lubricating Oils, 648.
Preservative.
— Coatings for Structural Materials. Report of Committee D-1, 329.
— Metallic Coatings. Report of Sub-Committee II, Committee A-5, 105.
Proportioning.
A Proposed Method of Estimating the Density and Strength of Concrete and of — the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and Concrete, 940. Discussion, 968.

Publications.
Papers and —. Report of Committee E-6, 437.
Public Works.
The Influence of the Work of the American Society for Testing Materials upon the Execution of —. Annual Address by the President, George S. Webster, 39.

Q

Quicklime.
Tentative Specifications for — for Structural Purposes, 533.

R

Railway Equipment.
Tentative Specifications for Non-Ferrous Alloys for — in Ingots, Castings, and Finished Car and Tender Bearings, 486.
Red Lead.
Tentative Specifications for —, 623.
Refractories.
—. Report of Committee C-8, 315.
Reinforced Concrete.
—. Report of Committee C-2, 210.
Progress Report of the Joint Committee on Standard Specifications for Concrete and —, 212.
Reinforcement.
Tentative Specifications for Cold-Drawn Steel Wire for Concrete —, 459.
Road Materials.
Road and Paving Materials. Report of Committee D-4, 375.
Rodding.
Variation in the Effect of — Concrete. F. E. Giesecke, 1008.
Rubber.
— Products. Report of Committee D-11, 412. Minority Report, 419. Discussion, 421.
Tentative Specifications for Insulated Wire and Cable: 30-per-cent Hevea —, 746.
Tentative Specifications for Cotton — -Lined Fire Hose for Private Fire Department Use, 773.
Tentative Specifications for Cotton — -Lined Fire Hose for Public Fire Department Use, 778.
Tentative Specifications for — Belting for Power Transmission, 795.
Tentative Specifications for — Insulating Tape, 802.
Tentative Specifications for — Gloves for Electrical Workers on Apparatus or Circuits Not Exceeding 3000 Volts to Ground, 805.

S

Saponification.
—. Report of Sub-Committee XIII, Committee D-2, 369.
Results of Cooperative Work for — Number on Mixture of Oils Submitted to Committee Members. Report of Sub-Committee XIII, Committee D-2, Appendix, 371.
Tentative Method of Test for — Number, 663.
Sampling.
Tentative Revision of Standard Methods of Laboratory — and Analysis of Coal, 837.

Sand.
Tentative Specifications for Gypsum Plastering —, 559.
Screen.
— Wire Cloth. Report of Committee D-14, 427.
Seamless.
Tentative Specifications for Lap-Welded and — Steel and Lap-Welded Iron Boiler Tubes, 461.
Sediment.
Tentative Method of Test for Water and — in Petroleum Products, by Means of Centrifuge, 670.
Water and —. Report of Sub-Committee XIV, Committee D-2, 373.
Sewer.
Clay and Cement — Pipe. Report of Committee C-4, 285.
Tentative Specifications for Clay — Brick, 527.
Shipping Containers.
—. Report of Committee D-10, 409.
Shock Strength.
A Test for — of Hardened Steel. C. E. Margerum, 876.
Sieve Analysis.
Tentative Method of Test for — of Aggregates for Concrete, 586.
Slags.
A Study of the Composition of Blast Furnace — Suitable for Concrete Aggregate. L. G. Carmick, 976. Discussion, 982.
Sludging.
Procedures in — Tests for Transformer Oils. Report of Committee D-9, Appendix II, 407.
Slump Test.
A Comparison of the Results of the — and the Flow Table in the Measurement of the Consistency of Concrete. W. L. Schwalbe, 983. Discussion, 988.
Soils.
Tests for — with Relation to Their Use in the Subgrade of Highways. A. T. Goldbeck and F. H. Jackson, 1057.
Spalling.
Tentative Method of Test for Resistance of Fire-Clay Brick to — Action, 577.
Spark Gaps.
Joint Comparative Tests of — for Testing Transformer Oils. Report of Committee D-9, Appendix I, 397.
Springs.
Magnetic Testing of —. T. Spooner and I. F. Kinnard, 883.
Staybolt.
Tentative Specifications for Hollow — Iron, 478.
Steel.
A Test for Shock Strength of Hardened —. C. E. Margerum, 876.
Comparative Tests of — at High Temperatures. R. S. MacPherran, 852. Discussion, 861.
Corrosion of Iron and —. Report of Committee A-5, 103. Discussion, 191.
Heat Treatment of Iron and —. Report of Committee A-4, 99.
Impact Tests on Cast —. F. C. Langenberg, 840. Discussion, 850.
Preparation of Iron and — Surfaces for Painting. Report of Sub-Committee XIV, Committee D-1, 345.
Proposed Revisions of Standards and Tentative Standards for —. Report of Committee A-1, Appendix, 75.

Steel (*Continued*):
- —. Report of Committee A-1, 66. Addendum, 87.
- Tentative Specifications for Boiler and Firebox — for Stationary Service, 447.
- Tentative Specifications for Carbon Tool —, 452.
- Tentative Specifications for — Plates for Forge Welding, 454.
- Tentative Specifications for Cold-Drawn — Wire for Concrete Reinforcement, 459.
- Tentative Specifications for Lap-Welded and Seamless — and Lap-Welded Iron Boiler Tubes, 461.
- Tentative Methods of Metallographic Testing of Iron and —, 817.
- Tentative Specifications for Iron and — Chain, 468.

Stress-Strain Measurements.
- — on Films of Drying Oils, Paints and Varnishes. H. A. Nelson, 1111. Discussion, 1135.

Subgrade.
- Tests for Soils with Relation to Their Use in the — of Highways. A. T. Goldbeck and F. H. Jackson, 1057.

Sulfur.
- — Determination and Differentiation. Report of Sub-Committee VII, Committee D-2, 365.
- Tentative Method of Test for Detection of Free — and Corrosive — Compounds in Petroleum Products, 643.
- Tentative Method of Test for — in Naphthas and Illuminating Oils, 644.

Summary of the Proceedings.
- — of the Twenty-fourth Annual Meeting, 11.

Surface.
- Preparation of Iron and Steel — for Painting. Report of Sub-Committee XIV, Committee D-1, 345.
- Tentative Specifications for High-Carbon Tar for — Treatment, Cold Application, 686.
- Tentative Specifications for Low-Carbon Tar for — Treatment, Cold Application, 688.
- Tentative Specifications for High-Carbon Tar for — Treatment, Hot Application, 694.
- Tentative Specifications for Low-Carbon Tar for — Treatment, Hot Application, 696.

Switch.
- Tentative Methods of Testing Transformer and — Oils, 737.

T

Tape.
- Tentative Specifications for Commercial Adhesive — for Electrical Purposes, 799.
- Tentative Specifications for Rubber Insulating —, 802.

Tar.
- Tentative Specifications for High-Carbon — for Surface Treatment, Cold Application, 686.
- Tentative Specifications for Low-Carbon — for Surface Treatment, Cold Application, 688.
- Tentative Specifications for High-Carbon — Cement for Use Cold in Repair Work (Cut-Back Product), 690.

Tar (*Continued*):
- Tentative Specifications for Low-Carbon — Cement for Use Cold in Repair Work (Cut-Back Product), 692.
- Tentative Specifications for High-Carbon — for Surface Treatment, Hot Application, 694.
- Tentative Specifications for Low-Carbon — for Surface Treatment, Hot Application, 696.
- Tentative Specifications for High-Carbon — Cement, 698.
- Tentative Specifications for Low-Carbon — Cement, 700.
- Tentative Specifications for Coal- — Pitch for Block Filler, 702.

Tender.
- Tentative Specifications for Non-Ferrous Alloys for Railway Equipment in Ingots, Castings, and Finished Car and — Bearings, 486.

Tensile Strength.
- A Method of Determining the — of Porcelain. F. H. Riddle and J. S. Laird, 1050.

Testing.
- Methods of —. Report of Committee E-1, 428.

Textile Materials.
- —. Report of Committee D-13, 425.

Tile.
- Drain —. Report of Committee C-6, 286.
- Hollow Building —. Report of Committee C-10, 324.
- Tentative Specifications for Clay Hollow Building — 547.
- Tentative Definitions of Terms Relating to Hollow —, 602.

Timber.
- —. Report of Committee D-7, 384.

Time of Set.
- — of Concrete. Watson Davis, 995. Discussion, 1007.

Tire.
- Tentative Specifications for Imperfections and Tolerances in 60-in. 17¼-oz. Square-Woven — Builder Fabric, 811.

Tolerances.
- Tentative Specifications for Imperfections and — in 60-in. 17¼-oz. Square-Woven Tire Builder Fabric, 811.

Tool.
- Tentative Specifications for Carbon — Steel, 452.
- Tentative Specifications for Wrapped Air Hose for Use with Pneumatic —, 784.
- Tentative Specifications for Braided Air Hose for Use with Pneumatic —, 788.

Transformer.
- Joint Comparative Tests of Spark Gaps for Testing — Oils. Report of Committee D-9, Appendix I, 397.
- Procedures in Sludging Tests for — Oils. Report of Committee D-9. Appendix II, 407.
- Tentative Methods of Testing — and Switch Oils, 737.

Transmission.
- Tentative Specifications for Rubber Belting for Power —, 795.

Tubes.
- Tentative Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler —, 461.

Tubes (*Continued*):
On Plastic Flow Through Capillary —. E. Buckingham, 1154. Discussion, 1157.
Tung Oil.
Tentative Revision of Standard Specifications for Purity of Raw —, 835.
Turpentine.
Tentative Specifications for —, 604.
—. Report of Sub-Committee XII, Committee D-1, 344.

V

Varnishes.
Stress-Strain Measurements on Films of Drying Oils, Paints and —. H. A. Nelson, 1111. Discussion, 1135.
Tentative Methods of Testing Insulating —, 722.
Viscosity.
—. Report of Sub-Committee V, Committee D-2, 362.
Tentative Method of Test for — of Fuel Oils and Other Oils of Similar —, 642.
Viscous.
A Study of Elastic — Deformation. P. G. Nutting, 1162. Discussion, 1169.
Voids.
A Proposed Method of Estimating the Density and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the — in Mortar and Concrete. A. N. Talbot, 940. Disscusion, 968.

W

Wall Board.
Tentative Specifications for Gypsum —, 560.
Water.
Tentative Method of Test for — in Petroleum Products, 666.
Tentative Method of Test for — and Sediment in Petroleum Products, by Means of Centrifuge, 670.
Tentative Method of Test for — in Bituminous Materials, 706.
— and Sediment. Report of Sub-Committee XIV, Committee D-2, 373.
Wax.
Paraffin —. Report of Sub-Committee III, Committee D-2, 360.
Tentative Method of Test for Melting Point of Paraffin —, 638.
Wear.
— Tests of Concrete. D. A. Abrams, 1013. Discussion, 1035.
Welding.
Tentative Specifications for Steel Plates for Forge —, 454.
Wheels.
Some Failures of Cast-Iron —, H. J. Force, 891. Discussion, 897.
Tentative Specifications for Cast-Iron Car —, 481.
White Lead.
Tentative Specifications for Basic Carbonate —, 619.
Tentative Specifications for Basic Sulfate —, 621.
Wire.
Copper —. Report of Committee B-1, 195.
Screen — Cloth. Report of Committee D-14, 427.

Wire (*Continued*):
  Tentative Specifications for Cold-Drawn Steel — for Concrete Reinforcement, 459.
  Tentative Specifications for Insulated — and Cable: 30-per-cent Hevea Rubber, 746.

Wrought Iron.
  Proposed Revisions of Standards and Tentative Standards for —. Report of Committee A-2, Appendix, 94.
  —. Report of Committee A-2, 90.

Z

Zinc.
  Tentative Specifications for — Oxide, 615.
  Tentative Specifications for Leaded — Oxide, 617.

AUTHOR INDEX.

A

Abrams, D. A.
  Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, 212.
  Wear Tests of Concrete, 1013.
  Discussion, 302, 1007, 1035, 1036, 1038.

Aupperle, J. A.
  Report of Committee A-5 on Corrosion of Iron and Steel, 103.
  Discussion, 191.

B

Barrier, E. A.
  Minority Report Regarding Revision of Present Cotton Rubber-Lined Fire Hose Specifications, 419.

Bassett, W. H.
  Report of Committee D-14 on Screen Wire Cloth, 427.
  Report of Committee E-4 on Metallography, 436.

Bates, P. H.
  Discussion, 982.

Baxter, Florus R.
  Report of Sub-Committee I, of Committee D-2, on Petrolatum, 354.
  Report of Sub-Committee VII, of Committee D-2, on Sulfur Determination and Differentiation, 365.

Berry, H. C.
  Report of Committee C-7 on Lime, 289.

Beyer, Albin H.
  Discussion, 1038.

Bingham, E. C.
  Discussion, 1157, 1169.

Bixby, W. H.
  Discussion, 872.

Blair, W. P.
  Discussion, 968.

Blanchard, A. H.
  Report of Committee D-4 on Road and Paving Materials, 375.

Boylston, H. M.
  Report of Committee A-4 on Heat Treatment of Iron and Steel, 99.

Breyer, F. C.
  Discussion, 1137, 1152.

Brown, H. C.
  Discussion, 904.

Buckingham, E.
  On Plastic Flow through Capillary Tubes, 1154.
  Discussion, 1159.

Burgess, G. K.
  Report of Sub-Committee II, of Committee A-5, on Preservative Metallic Coatings for Metals, 105.

Busby, H. S.
The Use of Secondary Reference Standards in Process Problems of Color Measurements, 1139.
Discussion, 1151.
Butterfield, E. E.
Discussion, 970.

C

Campbell, William.
Report of Committee B-2 on Non-Ferrous Metals and Alloys, 198; Addendum to Report of Committee B-2, 208.
Capp, J. A.
Report of Committee B-1 on Copper Wire, 195.
Report of Committee E-1 on Methods of Testing, 428.
Carmick, L. G.
A Study of the Composition of Blast-Furnace Slags Suitable for Concrete Aggregate, 976.
Carpenter, A. W.
Report of Sub-Committee XIV, of Committee D-1, on Preparation of Iron and Steel Surfaces for Painting, 345.
Cash, G.
Report of Sub-Committee IV, of Committee D-2, on Grease, 361.
Chapman, Cloyd M.
Report of Sub-Committee XI, of Committee D-1, on Paint Thinners Other than Turpentine, 342.
Report of Committee E-8 on Nomenclature and Definitions, 440.
Discussion, 988, 1007.
Clamer, G. H.
Discussion, 919.
Comstock, George F.
Report of Committee E-4 on Metallography, 436.
Discussion, 919.
Cooper, William A.
Report of Sub-Committee V, of Committee A-5, on Total Immersion Tests, 157.
Courtney, R. J.
Discussion, 904.
Crockatt, Charles C.
Report of Committee C-10 on Hollow Building Tile, 324.
Crum, R. W.
Discussion, 969, 972, 1035.
Curran, A. C.
Discussion, 905.

D

Davies, George C.
Report of Committee A-3 on Cast Iron, 96.
Davis, Watson.
Time of Set of Concrete, 995.
Discussion, 988, 1007.
Dean, Ernest W.
Problems Involved in the Development of Specifications for Motor Gasoline, 1094.
Report of Sub-Committee XII, of Committee D-2, on Flash, 368.

Delbridge, T. G.
Improvements in Apparatus for Testing Petroleum Products, 1100.
Report of Sub-Committee VI, of Committee D-2, on Color, 363.
Report of Sub-Committee IX, of Committee D-2, on Precipitation, 367.
Report of Sub-Committee XIV, of Committee D-2, on Water and Sediment, 373.
Report of Sub-Committee XVI, of Committee D-2, on Cloud and Pour Test, 374.
Dix, E. H., Jr.
Methods of Casting Manganese-Bronze Test Bars as a Check on Melts of Small Castings, 912.
Discussion, 850, 920.
Doke, G. E.
Discussion, 897, 909.

E

Emley, Warren E.
Report of Committee C-3 on Brick, 284.
Report of Committee C-11 on Gypsum, 326.

F

Faragher, W. F.
Report of Sub-Committee X, of Committee D-2, on Oxidation at High Temperatures, 368.
Farmer, F. M.
Report of Committee D-9 on Electrical Insulating Materials, 392.
Report of Committee D-11 on Rubber Products, 412.
Discussion, 421, 423.
Fieldner, A. C.
Report of Committee D-5 on Coal, 381.
Report of Committee D-6 on Coke, 383.
Fisk, G. F.
Discussion, 971.
Force, H. J.
Some Failures of Cast-Iron Wheels, 891.
Discussion, 909.
Francis, C. K.
Report of Sub-Committee III, of Committee D-2, on Paraffin Wax, 360.
Report of Sub-Committee VIII, of Committee D-2, on Distillation, 367.
The Refining of Petroleum, 1086.
Freeman, J. E.
Discussion, 1036.
French, D. K.
Report of Sub-Committee XIII, of Committee D-2, on Saponification, 369.
French, H. J.
Discussion, 861.
Fulweiler, W. H.
Report of Committee C-8 on Refractories, 315.

G

Gardner, H. A.
Report of Sub-Committee III, of Committee D-1, on Testing of Paint Vehicles, 333.
Discussion, 1135, 1152.

Gennet, C. W., Jr.
Discussion, 872.
Gibboney, J. H.
Report of Sub-Committee III, of Committee A-5, on Inspection of the Fort Sheridan, Pittsburgh and Annapolis Tests, 106.
Giesecke, F. E.
Variation in the Effect of Rodding Concrete, 1008.
Goldbeck, A. T.
Report of Committee C-9 on Concrete and Concrete Aggregates, 317.
Tests for Soils with Relation to Their Use in the Subgrade of Highways, 1057.
Discussion, 322.
Green, Henry.
Discussion, 1157, 1158, 1170, 1171.

H

Hall, J. H.
Report of Committee A-4 on Heat Treatment of Iron and Steel, 99.
Hallett, R. L.
Report of Committee D-1 on Preservative Coatings for Structural Materials, 329.
Hammond, George T.
Report of Committee C-4 on Clay and Cement Sewer Pipe, 285.
Harder, O. E.
Discussion, 322.
Hart, L. H.
Report of Committee C-7 on Lime, 289.
Hatt, W. K.
Discussion, 969, 989.
Hering, Rudolph.
Report of Committee C-4 on Clay and Cement Sewer Pipe, 285.
Herschel, Winslow H.
Report of Sub-Committee V, of Committee D-2, on Viscosity, 362.
Discussion, 1157, 1170, 1171.
Hollister, S. C.
Report of Committee C-2 on Reinforced Concrete, 210.
Holz, H. A.
Discussion, 868.
Hubbard, Prévost.
Report of Committee D-4 on Road and Paving Materials, 375.
Hull, Walter A.
Report of Committee C-10 on Hollow Building Tile, 324.
Humphrey, Richard L.
Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, 212.
Report of Committee C-2 on Reinforced Concrete, 210.

I

Ingalls, F. P.
Discussion, 1147.
Ingberg, S. H.
Discussion, 873.

J

Jackson, F. H.
Tests for Soils with Relation to Their Use in the Sub-Grade of Highways, 1057.

Job, Robert.
Discussion, 905.

Jury, A. E.
Report of Committee D-13 on Textile Materials, 425.

K

Kinnard, I. F.
Magnetic Testing of Springs, 883.

Kinney, W. M.
Discussion, 1038.

Kommers, J. B.
Discussion, 939.

L

Laird, J. S.
A Method of Determining the Tensile Strength of Porcelain, 1050.

Langenberg, F. C.
Impact Tests on Cast Steel, 840.
Discussion, 850.

Lunn, Charles A.
Report of Sub-Committee II, of Committee D-2, on Gas Absorbent Oil, 360.

Lyndon, George W.
Discussion, 900.

M

MacGregor, J. S.
Discussion, 1135, 1158.

Mackenzie, K. G.
Report of Committee D-2 on Petroleum Products and Lubricants, 351.

MacPherran, R. S.
Comparative Tests of Steels at High Temperatures, 852.
Discussion, 874, 875.

Marani, V. G.
Report of Committee C-11 on Gypsum, 326.

Marcher, R. J.
Discussion, 322, 1037.

Margerum, C. E.
A Test for Shock Strength of Hardened Steel, 876.
Discussion, 1081.

Marston, Anson.
Report of Committee C-6 on Drain Tile, 286.

Martin, C. B.
Report of Committee D-11 on Rubber Products, 412.

Mattimore, H. S.
Discussion, 1035, 1036.

McCabe, A. S.
Some Mechanical Properties of Hot-Rolled Monel Metal, 922.

McClumpha, H. E.
Discussion, 904.

Merica, P. D.
Report of Committee B-2 on Non-Ferrous Metals and Alloys, 198; Addendum to Report of Committee B-2, 208.
Some Mechanical Properties of Hot-Rolled Monel Metal, 922.

Moldenke, Richard.
Report of Committee A-3 on Cast Iron, 96; Addendum to Report of Committee A-3, 98.
Report of Committee D-6 on Coke, 383.
Discussion, 900, 905.

Moore, H. F.
Discussion, 850.

N

Nelson, H. A.
Stress-Strain Measurements on Films of Drying Oils, Paints and Varnishes, 1111.
Discussion, 1136.

Nemzek, L. P.
Report of Sub-Committee VI, of Committee D-1, on Definitions of Terms Used in Paint Specifications, 341.

Newlin, J. A.
Report of Committee D-7 on Timber, 384.
Report of Committee D-10 on Shipping Containers, 409.

Nutting, P. G.
A Study of Elastic Viscous Deformation, 1162.

P

Pfund, A. H.
Discussion, 1149.

Pickard, Glenn H.
Report of Sub-Committee V, of Committee D-1, on Linseed Oil, 334.

Purdy, R. C.
Report of Committee C-8 on Refractories, 315.

Provost, A. J., Jr.
Report of Committee C-4 on Clay and Cement Sewer Pipe, 285.

R

Riddle, F. H.
A Method of Determining the Tensile Strength of Porcelain, 1050.

Ripley, C. T.
Discussion, 907.

Rogers, Allen.
Report of Committee D-1 on Preservative Coatings for Structural Materials, 329.

S

Schwalbe, W. L.
A Comparison of the Results of the Slump Test and the Flow Table in the Measurement of the Consistency of Concrete, 983.
Discussion, 994.

Seaton, M. Y.
Testing of Plastic Calcined Magnesite for Use in Oxychloride Cements, 1039.

Shelley, H. T.
Report of Committee C-3 on Brick, 284.

Skirm, G. W.
Report of Committee D-13 on Textile Materials, 425.
Slater, W. A.
Discussion, 1036.
Smith, E. B.
Measurement of Impact, 1073.
Discussion, 1084.
Smith, H. E.
Report of Committee A-2 on Wrought Iron, 90.
Report of Sub-Committee XV, of Committee D-1, on Specifications for Pigments Dry and in Oil When Marketed in that Form, 350.
Speller, F. N.
Discussion, 874.
Spooner, A. P.
Discussion, 863, 874.
Spooner, T.
Magnetic Testing of Springs, 883.
Stewart, J. T.
Report of Committee C-6 on Drain Tile, 286.
Stratton, S. W.
Discussion, 422.

T

Talbot, A. N.
A Proposed Method of Estimating the Density and Strength of Concrete and of Proportioning the Materials by the Experimental and Analytical Consideration of the Voids in Mortar and Concrete, 940.
Discussion, 968, 972, 990.
Thompson, G. W.
Discussion, 1135, 1149.
Thompson, Sanford E.
Report of Committee C-9 on Concrete and Concrete Aggregates, 317.

V

Vassar, H. S.
Report of Committee D-9 on Electrical Insulating Materials, 392.
VanGundy, C. P.
Report of Committee D-2 on Petroleum Products and Lubricants, 351.
Veitch, F. P.
Report of Sub-Committee XII, of Committee D-1, on Turpentine, 344.
Discussion, 1137.
Vial, F. K.
Discussion, 902.
Von Schrenk, Hermann.
Report of Committee D-7 on Timber, 384.
Voorhees, S. S.
Report of Committee A-5 on Corrosion of Iron and Steel, 103.

W

Waltenberg, R. G.
Some Mechanical Properties of Hot-Rolled Monel Metal, 922.

Waring, F. M.
Report of Committee A-1 on Steel, 66; Addendum to Report of Committee A-1, 87.

Warwick, C. L.
Annual Report of the Executive Committee, 47.
Report of Committee E-1 on Methods of Testing, 428.
Report of Committee E-8 on Nomenclature and Definitions, 440.
Report of Committee E-6 on Papers and Publications, 437.

Waterhouse, G. B.
Discussion, 908.

Webster, George S.
Annual Report of the Executive Committee, 47.
Annual Address by the President—The Influence of the American Society for Testing Materials upon the Execution of Public Works, 39.
Discussion, 900, 905.

Williams, G. M.
Discussion, 992.

Wilson, R. E.
Discussion, 1171.

Wilson, T. R. C.
Report of Committee D-10 on Shipping Containers, 409.

Withey, M. O.
Discussion, 968.

Woodward, R. W.
Report of Committee D-14 on Screen Wire Cloth, 427.

Y

Yates, J. J.
Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, 212.

Young, C. D.
Discussion, 908.

Young, J. B.
Report of Committee A-2 on Wrought Iron, 90.